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Bus Systems

Model: All

Production: All

OBJECTIVES

After completion of this module you will be able to:

- Describe the operation of a basic bus system.
- Understand how signals and sensor information are shared between control units in a bus system.
- Identify the different bus systems currently used in BMW Group vehicles.
- Understand how bus networking technology is applied in BMW vehicles.
- Understand diagnostic techniques.

Introduction

Today's vehicles contain a wide variety of electronic devices and components. The total number of electronic components in motor vehicles is sure to increase substantially in the foreseeable future. Legislation as well as customers demand this continued development. Legislation is interested in improving the quality of exhaust emissions and reducing fuel consumption. Customer requirements are focussed on improving driving comfort and safety.

Control units that meet these requirements have long been utilized. Examples include control units employed in the area of the digital motor electronics and airbag systems.

The complexity of the realized functions calls for data exchange between the control units. Conventionally, the data is transmitted via signal lines. However, in view of the increase in complexity of the control unit functions, this type of data exchange can now be realized only with ever growing expenditure.

Originally autonomous processes of individual control units are being coupled to an ever increasing extent via bus systems. This means that the processes are distributed, implemented throughout the vehicle systems network and interact in co-ordinated functions.

The data exchange within the systems network is therefore constantly increasing. This data exchange also enables many new functions, which benefit increased road safety and enhanced driving comfort.

These requirements can no longer be realized with the previous vehicle electrical systems and networks.

The increasing use of electrical and electronic components in motor vehicles is limited by various factors:

- Increasing scope of wiring/cabling
- Higher production costs
- Increased space requirement in the vehicle
- Component configurations that are difficult to manage
- Reduced reliability of overall system

Networks are used in the vehicle electrical system with the aim of minimizing these disadvantages. These networks are referred to as bus systems.

Bus systems enable networking of the individual control units in the vehicle via "serial interfaces". This provides various advantages that facilitate the use of the systems in motor vehicles.

Advantages of Bus Systems

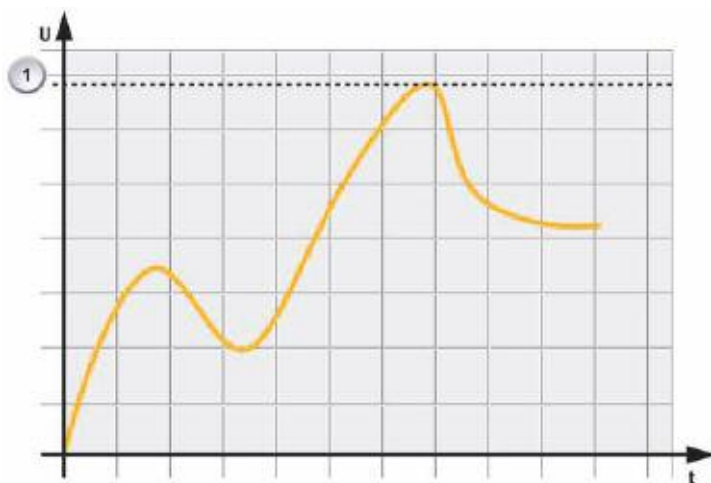
- Higher reliability of overall system
- Reduced extent of wiring/cabling
- Reduction in the number of individual cables
- Reduced cross sections of wiring harnesses
- Flexible installation of cables
- Multiple use of sensors
- Transmission of complex data possible
- Higher flexibility for system modifications
- Expansion of scope of data possible at any time
- Implementation of new functions for the customer
- Efficient diagnosis
- Lower hardware costs

Types of Transmission

Analog Transmission

The term analog comes from the Greek (analogos) and means corresponding to, analogous to.

Analog representation of data (= information) is based on representation by a continuously changing physical variable that is directly proportional to the data.



Index	Explanation
1	Maximum
U	Voltage
t	Time

Analog Signal

A characteristic of an analog signal is that it can assume any value between 0% and 100%. The signal is therefore infinitely variable.

Examples: Pointer measuring instruments, mercury thermometer, hands of a watch.

When listening to music, for example, the ear receives the analog signals (constantly changing sound waves). This sound is represented in the same way in electrical devices (audio system, radio, telephone etc.) by means of continuously changing voltages.

However, when such an electrical signal is transferred from one device to another, the information arriving at the receiver is no longer exactly the same as what was sent by the transmitter.

This is due to interference factors such as:

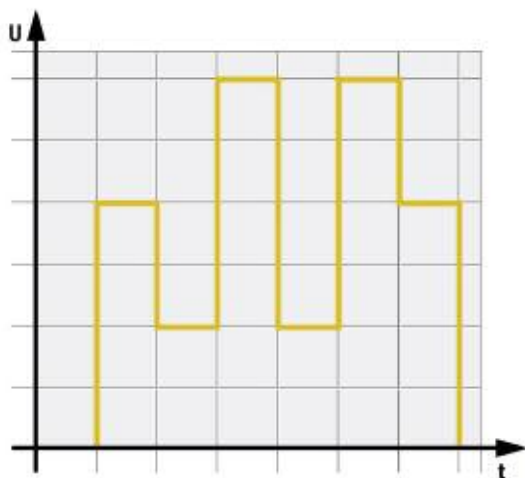
- Cable length
- Line resistance of the cable
- Radio waves
- Mobile radio signals

The analog transmission of information in vehicle applications is not feasible for safety and reliability reasons. In addition, the changes in voltages would be much too small so that reliable values could not be represented (ABS, airbag, engine management etc.).

Digital Transmission

The term digital originates from the Latin word *digitus* and means finger or toe.

Digital is therefore everything that can be counted on a few fingers or put more accurately everything that can be divided into discrete steps.



Index	Explanation
U	Voltage
t	Time

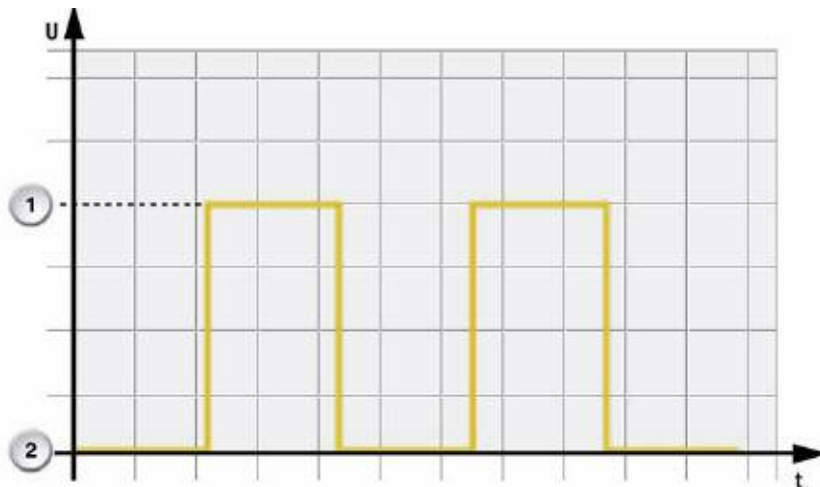
Digital representation involves the representation of constantly changing variables in numerical form. Particularly in computers, all data are represented as a sequence of zeros and ones (binary). Digital is therefore the opposite of analog.

Examples: Digital multimeter, digital clock, CD, DVD.

Binary Transmission

The word bi comes from the Greek and means two.

Binary Signal



Index	Explanation	Index	Explanation
1	High	U	Voltage
2	Low	t	Time

A binary signal therefore has only two possible states: 0 and 1 or High and Low.

Examples:

- Lamp lights - lamp does not light
- Relay has dropped out - relay has picked up
- Voltage is applied - voltage is not applied

All symbols, images or even sounds consist of a certain series of binary characters such as 10010110. With this binary code, the computer or the control unit can process information or send the information to other control units.

Signal Level

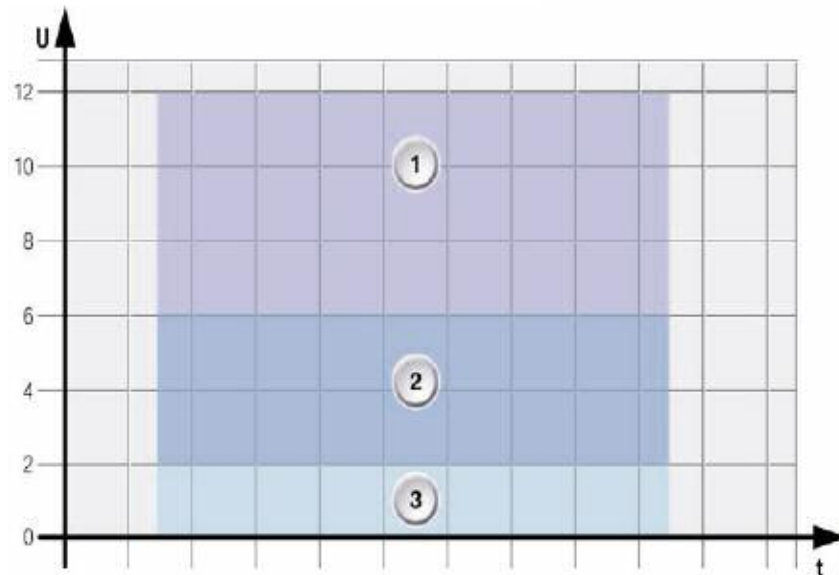
In order to be able to clearly distinguish between the two states High and Low in motor vehicle applications, a clearly defined range is assigned to each state:

- The High range is between 6 V and 12 V
- The Low range is between 0 V and 2 V

The range between 2 V and 6 V is the so called prohibited range that is used for fault detection purposes.

Coded Representation

Signal level



Index	Explanation	Index	Explanation
1	High range	U	Voltage
2	Prohibited range	t	Time
3	Low range		

A code is a distinct set of rules for depicting a character set in another character set.

An example of a code is the Morse alphabet. Each letter of the alphabet and the numbers are encrypted by signals of different lengths.

In Morse code, the well-known distress signal SOS (save our souls) is:

short short short	long long long	short short short
S	O	S

The code is used to convert information that is represented in encrypted form into another form of representation where the information content is not changed.

Important codes in computer engineering are ASCII and hexadecimal code.

For example, a person using a computer presses the D key on the keyboard. The letter D is then represented (coded) as a binary sequence 0100 0100. This character sequence is then sent in the form of an electrical signal from the keyboard via the cable to the computer. The computer interprets (decodes) this character sequence correctly as the letter D.

The character sequence and its electrical signal are known as coded information.

Bit and Byte

All information in computers is stored as bits (binary digit = smallest information unit). All data (letters, numbers, sounds, images etc.) must therefore be converted into a binary code for processing in the computer.

The most commonly used systems and codes use eight bits for the purpose of representing a character.

Eight bits are combined to form one byte, allowing 256 characters to be coded.

Larger Units of Bytes

The conversion does not correspond exactly to the factor 1000 but rather the factor 1024.

- 1 Kilobyte (KB) = 210 bytes, i.e. 1024 bytes
- 1 Megabyte (MB) = 220 bytes, i.e. 1024 KB (1.048.576 bytes)
- 1 Gigabyte (GB) = 230 bytes, i.e. 1024 MB (1.073.741.824 bytes)

Overview of Bus Systems

In principle, a distinction is made between two groups of bus systems:

- Main bus systems
- Sub-bus systems

Main bus systems are responsible for cross system data exchange. Sub-bus systems exchange data within the specific system. These systems are used to exchange relatively small quantities of data in specific systems.

Main Bus Systems

The following busses are used as main bus systems:

Main bus system	Data rate	Bus structure
K-Bus*	9.6 kbits/s	Linear -one-wire
D-Bus	10.5 - 115 kbits/s	Linear - one-wire parallel
CAN	100 kbits/s	Linear - two-wire parallel
D-CAN	500 kbits/s	Linear - two-wire parallel
K-CAN	100 kbits/s	Linear - two-wire parallel
K-CAN 2	500 kbits/s	Linear - two-wire parallel
F-CAN	500 kbits/s	Linear - two-wire parallel
PT-CAN	500 kbits/s	Linear - two-wire parallel
PT-CAN 2	500 kbits/s	Linear - two-wire parallel
<i>byteflight</i>	10 Mbits/s	Star structure - fiber optics conductor
MOST	22.5 Mbits/s	Ring structure - fiber optics conductor
FlexRay	10 Mbits/s	Star- two wire

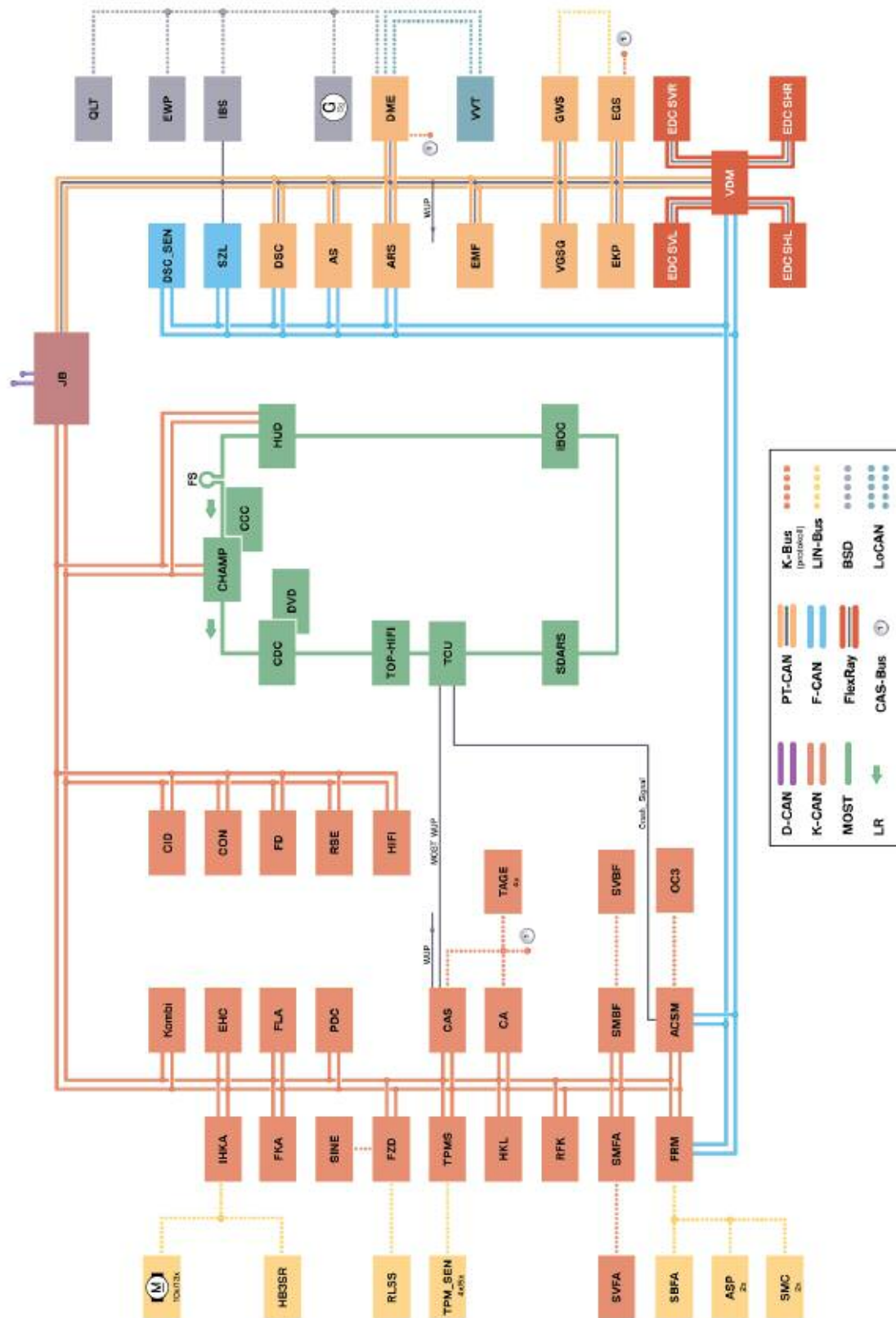
* Also known to as I-Bus in earlier models

Sub-bus Systems

The following busses are used as sub-bus systems:

Main bus system	Data rate	Bus structure
K-Bus protocol	9.6 kbits/s	Linear - one-wire
BSD	9.6 kbits/s	Linear - one-wire
DWA-Bus	9.6 kbits/s	Linear - one-wire
LIN-Bus	9.6-19.2 kbits/s	Linear - one-wire

E70 Bus Overview



Main Bus Systems

K-CAN

K-CAN stands for Karosserie (body) Controller Area Network. CAN was developed by Robert Bosch GmbH as the bus system for motor vehicles.

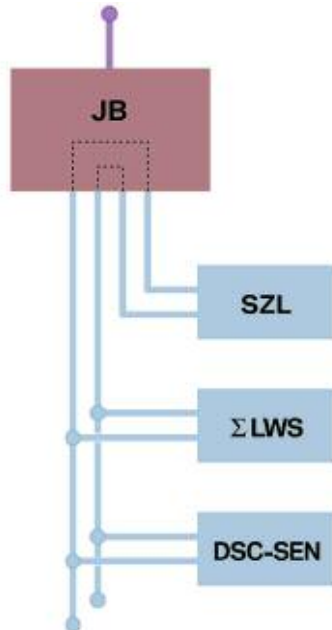
The task of the K-CAN is to transmit information in the area of the vehicle body.

As a twisted two-wire copper line, the K-CAN operates at a transmission rate of 100 kbits/s.

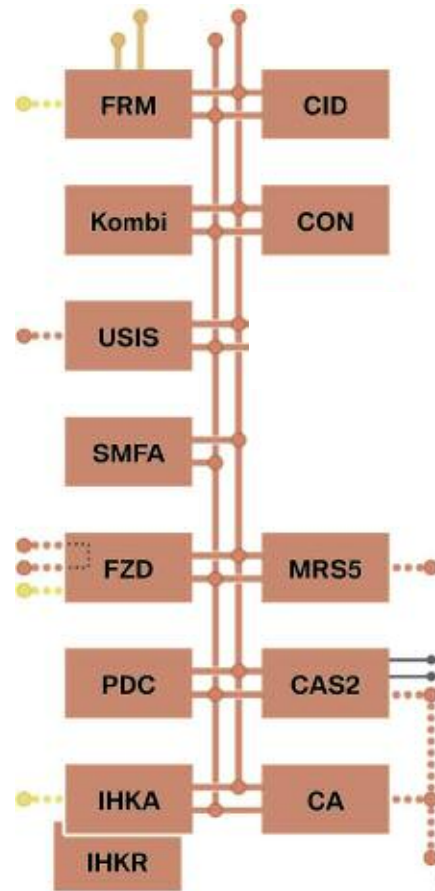
A further bus in the CAN family is the F-CAN.

F-CAN stands for Fahrwerk (chassis) Controller Area Network. This bus is structured and functions in exactly the same way as the K-CAN. However, the F-CAN is used exclusively for data transmission of the chassis/suspension components such as the dynamic stability control for example.

F-CAN on the E90



K-CAN on the E90



Advantages of CAN

The advantages of the CAN-Bus are:

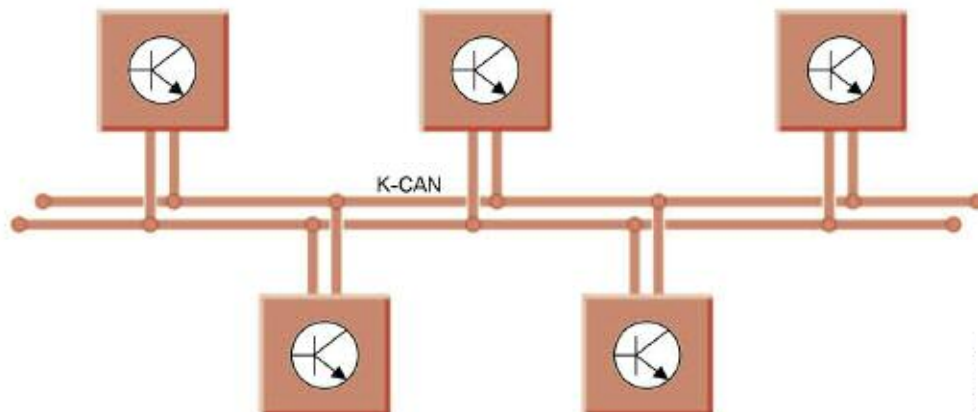
- Higher data transmission speed compared to conventional wiring
- Improved electromagnetic compatibility (EMC)
- Improved emergency operation characteristics

The body controller area network, abbreviated K-CAN, is used in BMW vehicles to inter-link components of the comfort and body electronics such as lamp control, seat adjustment and air conditioning.

The transmission rate is 100 kbits/s.

K-CAN is based on linear topology, i.e. it conforms to a bus structure.

Each terminal unit (node, control unit) in a network with a bus structure is connected with a common line.



The K-CAN is a multi-master bus. Each control unit that is connected to the bus can send messages.

The control units communicate event controlled. The control unit wishing to send data sends a message when the bus is free. If the bus is not free, the message with the highest priority is sent.

Since there are no receive addresses, each control unit receives every sent message. Consequently, further receiver stations can be easily added to the system during operation. Neither the software nor the hardware needs to be changed.

Two-wire copper lines are currently used for data transmission. However, solutions based on glass fiber or plastic fiber optics conductors are also possible. Fiber optics conductors are sensitive to high temperatures as occur in the engine compartment. Both lines are twisted to minimize interference.

The advantage of using two-wire lines is that it is possible to fall back on a one-wire line in the event of a fault.

Advantages:

- Easy to install
- Easy to expand
- Short lines
- Emergency operation on one line

Disadvantages:

- Network expansion limited
- Intricate access methods

Terminating Resistor

From an electrical point of view, a current carrying conductor always has an ohmic, inductive and capacitive resistance. When transmitting data from point "A" to point "B", the total sum of these resistances has an effect on data transmission. The higher the transmission frequency, the more effective the inductive and capacitive resistance. Ultimately, it is possible that a signal, which is no longer identifiable, is received at the end of the transmission line. For this reason, the line is "adapted" by terminating resistors, ensuring the original signal is retained.

Inductive resistance occurs, for example, as the result of the coil effect in the line. Capacitive resistance occurs, for example, by installing the line parallel to the vehicle body.

The terminating resistors used in a bus system vary.

They generally depend on the following parameters:

- Frequency of data transmission on the bus system
- Inductive or capacitive load on the transmission path
- Cable length for data transmission

The longer the line, the greater the inductive component of the line.

The control units are divided into basic control units that are always installed (e.g. instrument cluster in the E9x vehicles) and the remaining control units. The resistance value determines this division.

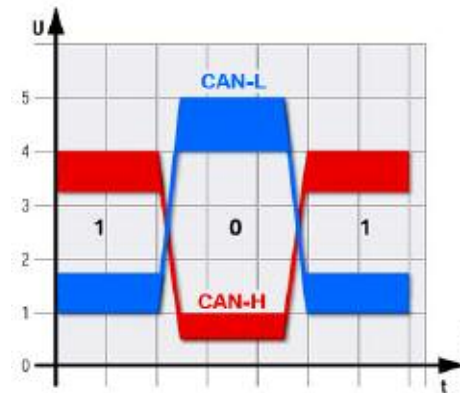
Terminating resistors are used to ensure exact signal progression in the bus systems. These terminating resistors are located in the control units of the bus systems.

If the voltage level changes due to a defective terminating resistor. This change in voltage affects the CAN system. Communication between the bus users no longer operates correctly.

Voltage level on the K-CAN:

- Logic 0 is when the voltage level changes back to low.
- Logic 1 state is assumed when the voltage level of the CAN-High switches from low to high.

The voltage difference between the CAN-H and CAN-L lines is 3 V when a dominant bit is transmitted on the K-CAN.



In order to obtain a clear idea of whether the CAN-Bus is functioning properly, you must be able to observe activity on the bus. You do not need to analyze the individual bits; you simply need to observe whether or not the CAN-Bus is working. The oscilloscope test can state that, "the CAN-Bus is probably operating without faults".



CH1: Probe tip 1, range 2 V/Div;
DC coupling

CH2: Probe tip 2, Range 2 V/Div;
DC coupling

Time: 100 μ s/Div

When you measure the voltage between the K-CAN Low line (or K-CAN High line) and the ground, you receive a rectangle-like signal in the following voltage ranges:

Voltage measurement at the K-CAN are:

K-CAN Low to ground: $V_{min} = 1$ volts and $V_{max} = 5$ volts

K-CAN High to ground: $V_{min} = 0$ volts and $V_{max} = 4$ volts



No defined resistance test can be carried out on the K-CAN data bus as the resistance varies generally $> 720K\Omega$ depending on the internal switching logic of the control units.

The K-CAN is operated as a one-wire bus if:

- There is a break in a CAN data line (core)
- There is a short to ground on a CAN data line (core)
- There is a short to the supply voltage UB+ on a CAN data line (core)

The bus systems used to date are also used in the F01/F02. The K-CAN is responsible for communication of the components with a low data transfer rate. The K-CAN is also connected to the other bus systems via the central gateway module.

The K-CAN is set up as line topology. Some control units in the K-CAN have a LIN-Bus as sub-bus. The K-CAN has a data transfer rate of 100 kBit/s and is designed as a twisted pair of wires. The K-CAN has the possibility to be operated as a single-wire bus in the event of a fault.

The K-CAN control unit is wakened via the bus, without an additional wake-up line. The following is an example of the control units which are fitted in the K-CAN of an F01/F02:

- CID Central Information Display
- CON Controller
- EHC, Electronic Height Control
- FD Rear Display
- FD2 Rear Display 2
- FKA, rear heater / air-conditioning system
- HiFi, hi-fi amplifier
- HKL, luggage compartment lid lift
- HUD, Head-Up Display
- IHKA, integrated heater/air conditioning system*
- SMBF passenger seat module*
- SMBFH rear passenger seat module*
- SMFA driver seat module*
- SMBFH rear module on driver' seat side*
- TPMS, Tire Pressure Monitoring System
- TRSVC panoramic camera*
- VSW, video switch
- ZGM, central gateway module

K-CAN 2

First introduced with BN2020 in the F01, the K-CAN 2 is responsible for communication of the control units with a high data transfer rate. The K-CAN 2 is also connected to the other bus systems via the central gateway module (ZGM). A LIN-Bus as a sub-bus is connected to all control units in the K-CAN 2.

The K-CAN 2 can be wakened via any of these sub busses, without an additional (hard-wire) wake-up line. This is represented by the “wake authorized” symbol next to all of the control units of K-CAN 2 on the Bus Overview. (See bus chart below).

To provide a rapid start enable, the CAS has an additional redundant bus connection to the DME. On this CAS-Bus, the data are transferred per K-Bus protocol.

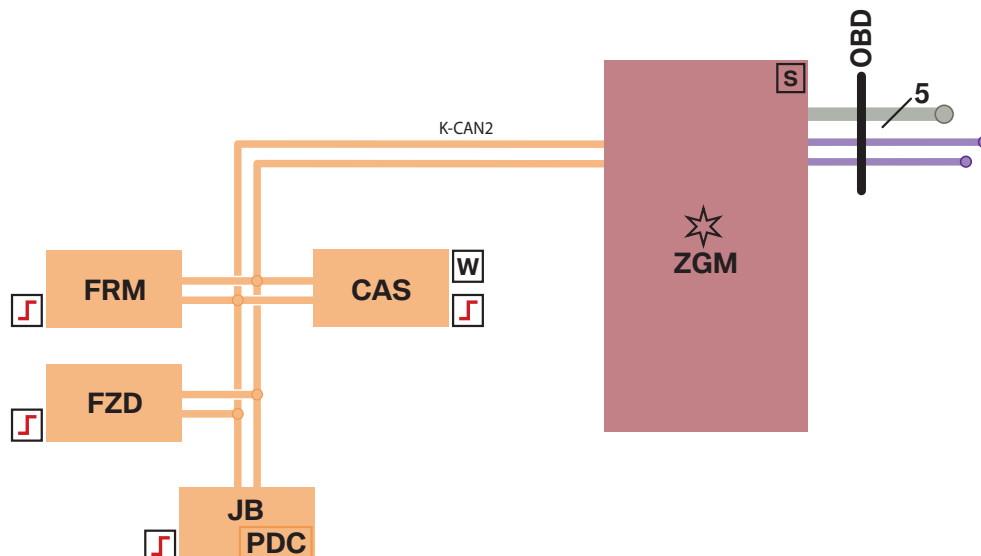
The K-CAN 2 is similar to PT-CAN in that it has a data transfer rate of 500 kBit/s, it is designed as a twisted pair with a measured a resistance of 60 Ω .

The following control units are fitted in the KCAN 2:

- CAS Car Access System
- FRM, footwell module
- FZD, roof functions center
- JBE, junction box electronics
- PDC, Park Distance Control (integrated in JBE)
- ZGM, central gateway module

The terminal resistors in the K-CAN 2 are located in the following control units:

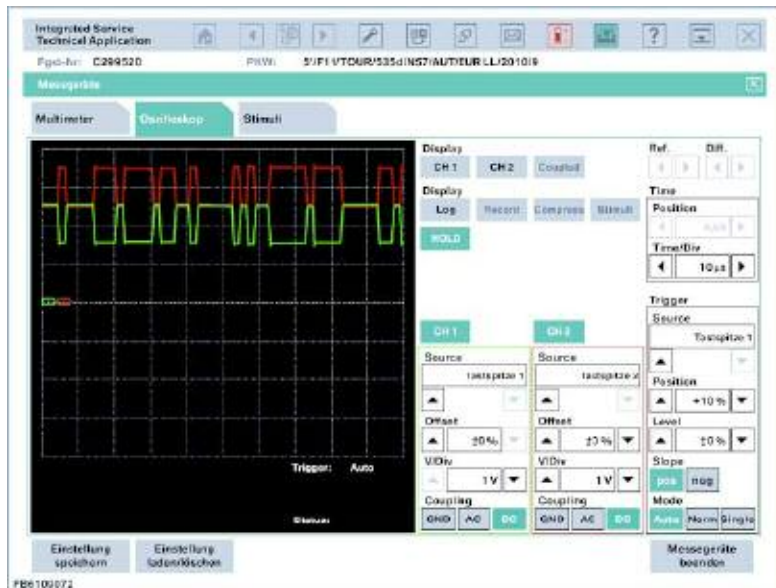
- Central gateway module
- Junction box electronics



When you measure the voltage between the K-CAN 2 Low line (or K-CAN 2 High line) and the ground, you receive a rectangle-like signal in the following voltage ranges:

CAN Low to ground: $V_{min} = 1.5$ volts and $V_{max} = 2.5$ volts

CAN High to ground: $V_{min} = 2.5$ volts and $V_{max} = 3.5$ volts



**CH1: Test probe 1, range 1 V/Div;
DC coupling**

**CH2: Test probe 2, range 1 V/Div;
DC coupling**

Time: 10 μ s/Div

Values of the terminating resistors on the K-CAN:

- 2 X 120 Ω resistors which equal a to measured resistance between wires of 60 Ω .

Inspection procedure for resistance test on any CAN-Bus:

- The CAN-Bus must be de-energized.
- No other testing equipment must be in use (connected in parallel).
- The measurement is taken between the CAN Low and CAN High lines.
- The actual values may differ from the setpoint values by a few Ω .

In order to prevent signal reflection, 2 CAN-Bus users (at the extremities of the powertrain CAN network) with 120 Ω each are terminated. The two terminal resistors are connected in parallel and form an equivalent resistance of 60 Ω . When the supply voltage is switched off, this equivalent resistance can be measured between the data lines. In addition, the individual resistors can be tested independently of one another.

Information on the measurement with 60 Ω : Disconnect an easily accessible control unit from the bus. Then measure the resistance on the connector between the CAN Low and CAN High lines.



When measuring K-CAN 2 voltage, the Oscilloscope (IMIB) settings should be the same as for the PT-CAN, or any “high” speed CAN.

PT-CAN

PT-CAN stands for Powertrain Controller Area Network. CAN was developed by Robert Bosch GmbH as the bus system for motor vehicles.

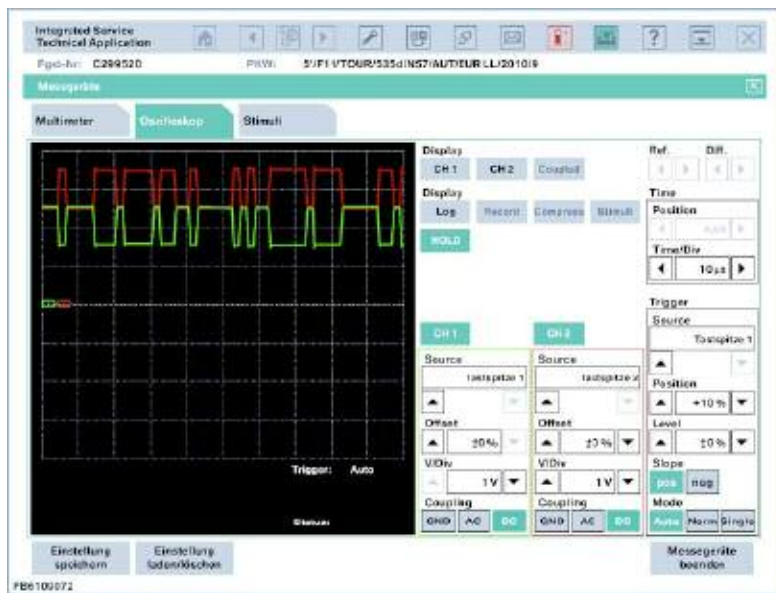
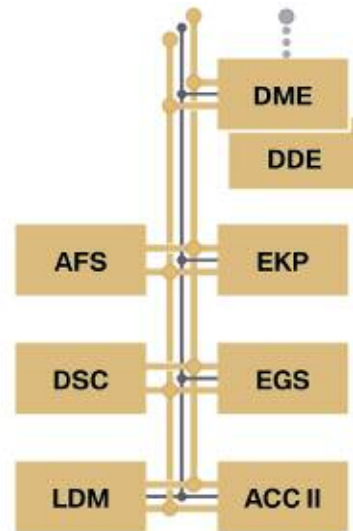
The PT-CAN has a transmission rate of 500 kbit/s and prior to the FlexRay was the fastest (hard wire) CAN-Bus used in BMW vehicles. Most of the busses that were introduced after it use similar design.

This bus connects all control units and modules belonging to the drive train. All bus users are connected in parallel.

The special feature of this CAN-Bus is that, instead of two lines, it is equipped with three lines.

The third line is used as a wake-up line and has nothing to do with actual operation of the CAN-Bus.

E90 PT-CAN



**CH1: Test probe 1, range 1 V/Div;
DC coupling**

**CH2: Test probe 2, range 1 V/Div;
DC coupling**

Time: 10 μ s/Div

When you measure the voltage between the PT-CAN Low line (or PT-CAN High line) and the ground, you receive a rectangle-like signal in the following voltage ranges:

CAN Low to ground: $V_{min} = 1.5$ volts and $V_{max} = 2.5$ volts

CAN High to ground: $V_{min} = 2.5$ volts and $V_{max} = 3.5$ volts



These values are approximate values and can vary by a few hundred mV depending on the bus load.

Note: For more information regarding CAN-Bus system diagnosis refer to:

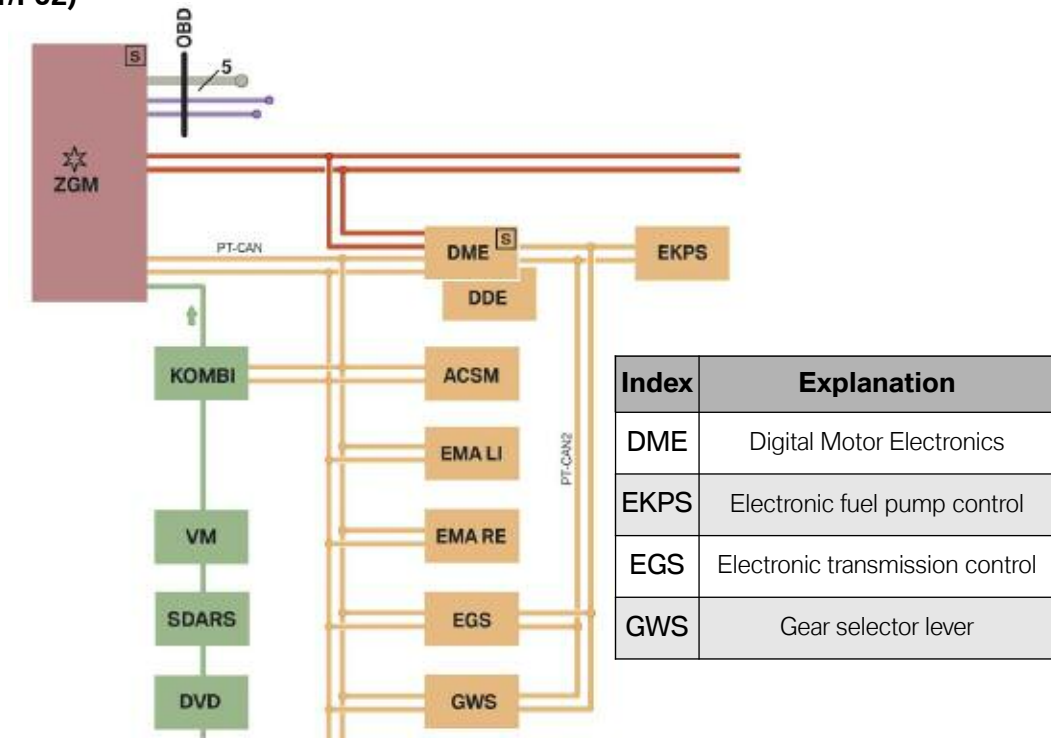
- SI B61 03 03 CAN-Byteflight Bus Diagnosis

- FUB-DAA0701FB-656135001 Checking the CAN bus signal

PT-CAN 2

Also introduced with BN2020 in the F01 the PT-CAN 2 forms a redundancy for the PT-CAN in the area of the engine management system and also transfers signals to the fuel pump control. PT-CAN 2 is similar to the PT-CAN in that it has a data transfer rate of 500 kBit/s and is designed as a twisted pair with an additional wake-up line. It also incorporates 2 (120 Ω) resistors which equal to a measured resistance between the wires of 60 Ω.

PT-CAN 2 (F01/F02)



The terminal resistors in the PT-CAN 2 are located in the following control units:

- Digital Motor Electronics
- Control unit for electric fuel pump

As with PT-CAN, when you measure the voltage between the PT-CAN2 Low line (or PT-CAN 2 High line) and the ground, you receive a rectangle-like signal in the following voltage ranges:

CAN Low to ground: V min = 1.5 volts and V max = 2.5 volts

CAN High to ground: V min = 2.5 volts and V max = 3.5 volts



When measuring PT-CAN 2 voltage, the Oscilloscope (IMIB) settings should be the same as for the PT-CAN and K-CAN 2 (refer to these for an sample of the PT-CAN 2 scope pattern).

ICM-CAN

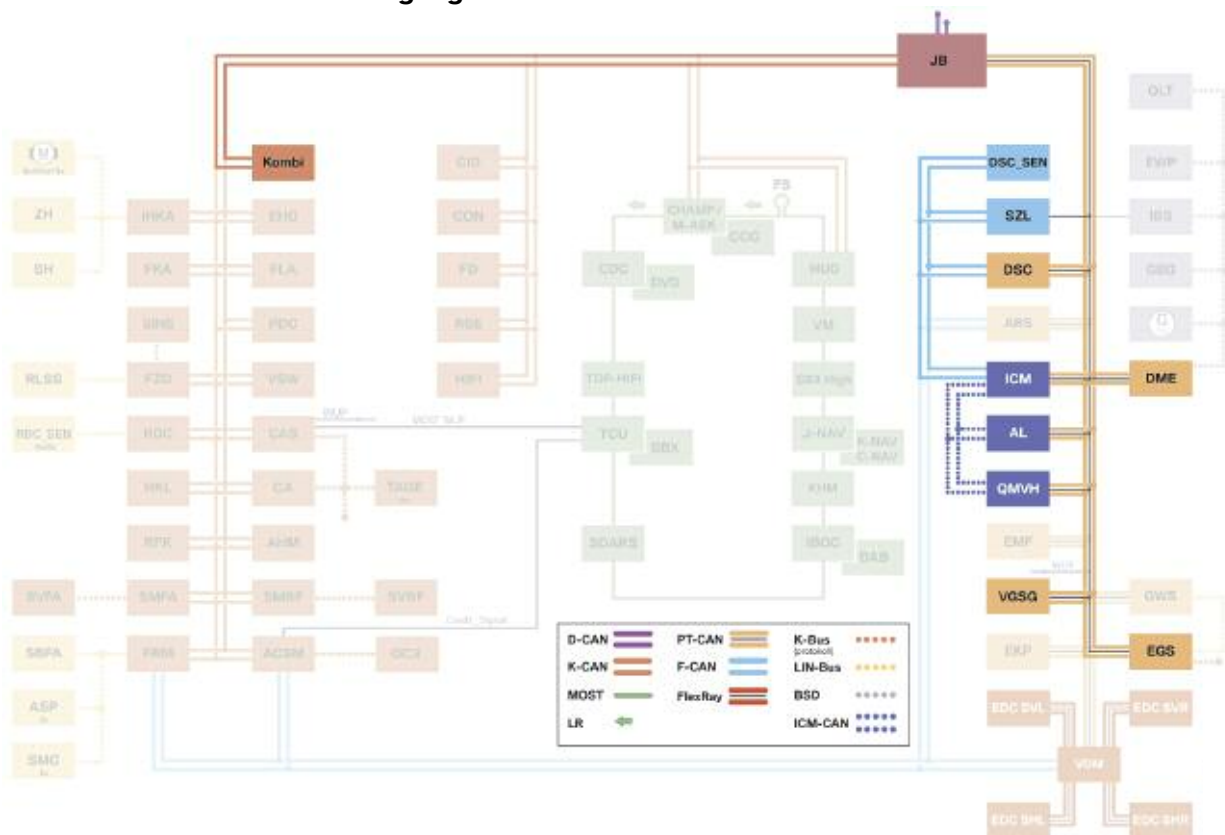
One of the differences between the E71 and the E70 is the introduction of a new control unit known as Integrated Chassis Management (ICM). The ICM coordinates longitudinal and lateral dynamic control functions, which include the familiar Active Steering and the Dynamic Performance Control [with QMVH] Currently available in the E71 and E70M and E71M.

Despite the fact that the PT-CAN and F-CAN work at a high bit rate of 500 kbps, they would have been overloaded by the signals from the ICM and QMVH control units. For this reason, the ICM-CAN sub-bus was introduced.

The ICM-CAN was integrated into the BN2000 network as a new bus system especially designed for the ICM control unit functions. It connects the ICM, AL and QMVH control units.

The diagram shows the control units and bus systems that are related for the dynamic driving systems.

E71 bus chart with ICM-CAN highlighted



Note: In BN200 vehicles the ICM control unit is connected to an expanded version of the FlexRay eliminating the need of the ICM-CAN.

The ICM-CAN is a two-wire bus on which data is transmitted at 500 kBps. The two terminating resistors, each with 120 Ω , are located in the ICM and QMVH control units.

The ICM-CAN cabling in the vehicle varies considerably between the two variants with/without Active Steering.

If Active Steering is fitted, the ICM-CAN is routed from the ICM control unit to the AL control unit. The ICM-CAN is picked up in the AL control unit and forwarded to the QMVH control unit.

If Active Steering is not fitted, the ICM-CAN line is routed directly from the ICM control unit to the QMVH control unit.

These control units use the ICM-CAN to exchange setpoint values and actual values, as well as status signals. These signals are only required locally for implementing the Dynamic Performance Control and Active Steering functions.

In contrast, signals that the dynamic driving systems exchange with other control units are still transmitted via the PT-CAN. The PT-CAN is also the bus system via which the ICM, AL and QMVH control units communicate with the diagnostic system.

The ICM control unit does not therefore perform the function of a diagnostics gateway.

As with PT-CAN and K-CAN2, when you measure the voltage between the ICM-CAN Low line (or ICM-CAN High line) and the ground, you receive a rectangle-like signal in the following voltage ranges:

CAN Low to ground: $V_{\min} = 1.5$ volts and $V_{\max} = 2.5$ volts

CAN High to ground: $V_{\min} = 2.5$ volts and $V_{\max} = 3.5$ volts



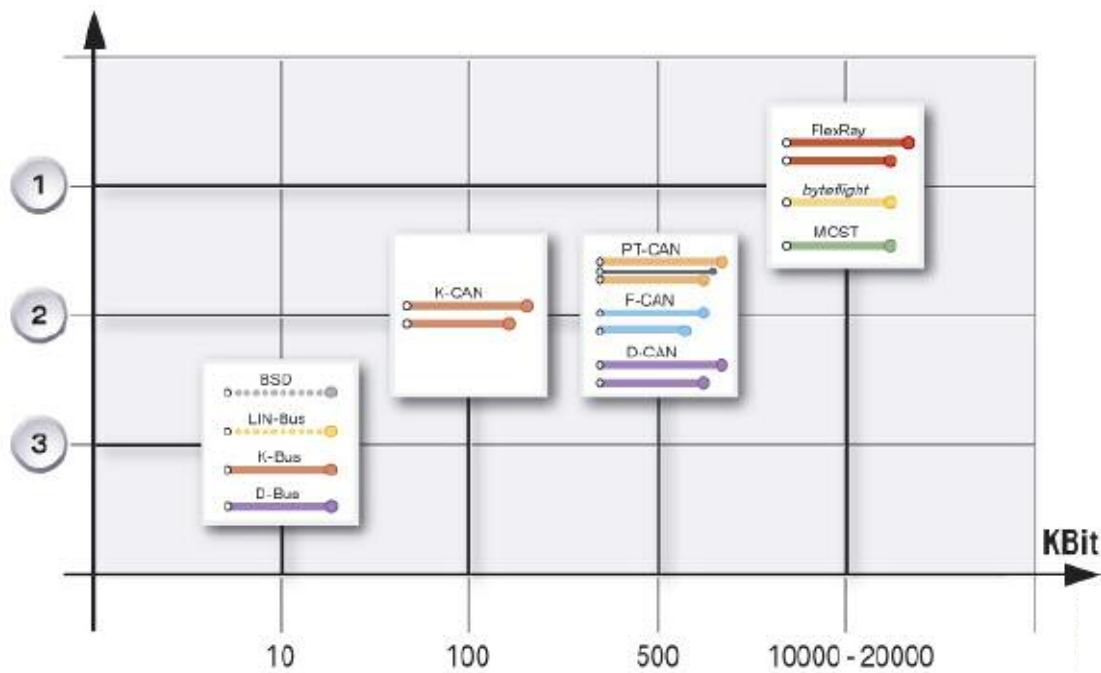
When measuring ICM-CAN voltage, the Oscilloscope (IMIB) settings should be the same as for the PT-CAN and K-CAN 2 (refer to these for an sample of the ICM-CAN scope pattern).

FlexRay

In the future, driving dynamics control systems, driver assistance systems and their innovative interconnection will be ever more important for the differentiation of the BMW badge. Since today's networking systems using the CAN-Bus have already reached their limit, it is necessary to find a suitable alternative for CAN.

In co-operation with Daimler Chrysler AG and the semiconductor manufacturers Freescale (formerly Motorola) and Philips, BMW AG founded the FlexRay consortium in 1999 for the purpose of developing innovative communication technology.

The consortium was soon joined by further partners, including Bosch and General Motors and to date, the Ford Motor Company, Mazda, Elmos and Siemens VDO have also decided to join. In the meantime, almost all significant car makers and suppliers throughout the world have joined the FlexRay consortium.



Index	Explanation
1	Real time capabilities, deterministic (strictly defined) and redundant
2	Conditional real time capabilities - sufficient for control systems
3	No real time capabilities

FlexRay is a new communication system which aims at providing reliable and efficient data transmission with real-time capabilities between the electrical and mechatronic components for the purpose of interconnecting innovative functions in motor vehicles, both today and in the future.

Development of the new FlexRay communication system was prompted by the ever growing technological requirements placed on a communication system for interconnecting control units in motor vehicles and the realization that an open and standardized solution was needed for infrastructure systems.

FlexRay provides an efficient protocol for real-time data transmission in distributed systems as used in motor vehicles.

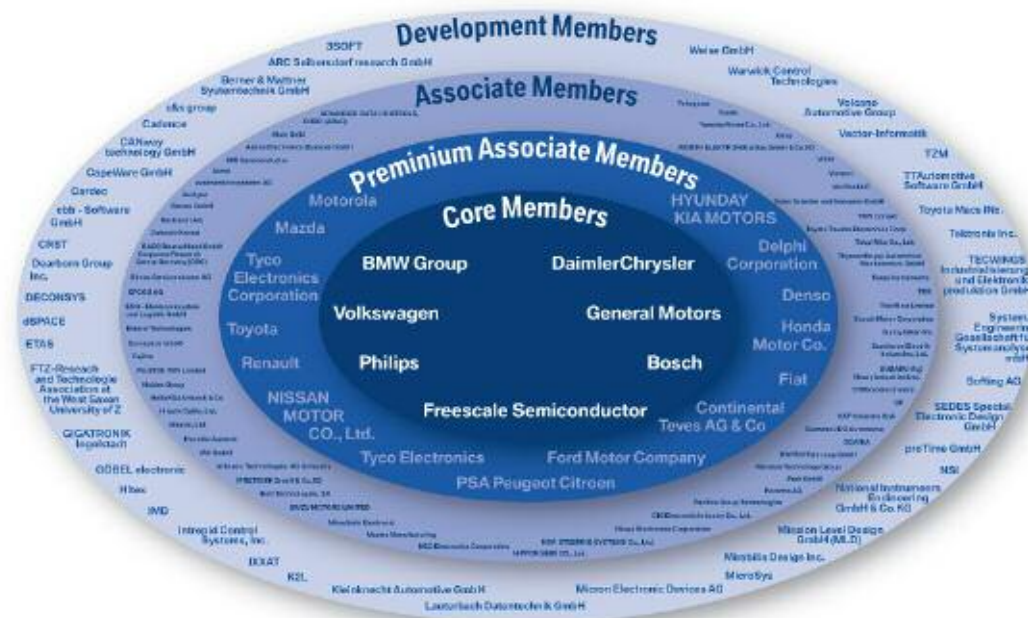
With a data transmission rate of 10 Mbits/s, the FlexRay is distinctly faster than the data buses used in the area of the chassis, drive train and suspension of today's motor vehicles.

In addition to the higher bandwidth, FlexRay supports deterministic data transmission and can be configured such that reliable continued operation of remaining communication systems is enabled even in the event of individual components failing.

What are the advantages of FlexRay?

- High bandwidth (10 Mbits/s compared to 0.5 Mbits/s of the CAN)
- Deterministic (= real-time capabilities) data transmission
- Reliable data communication
- Supports system integration
- Standard in automotive industry

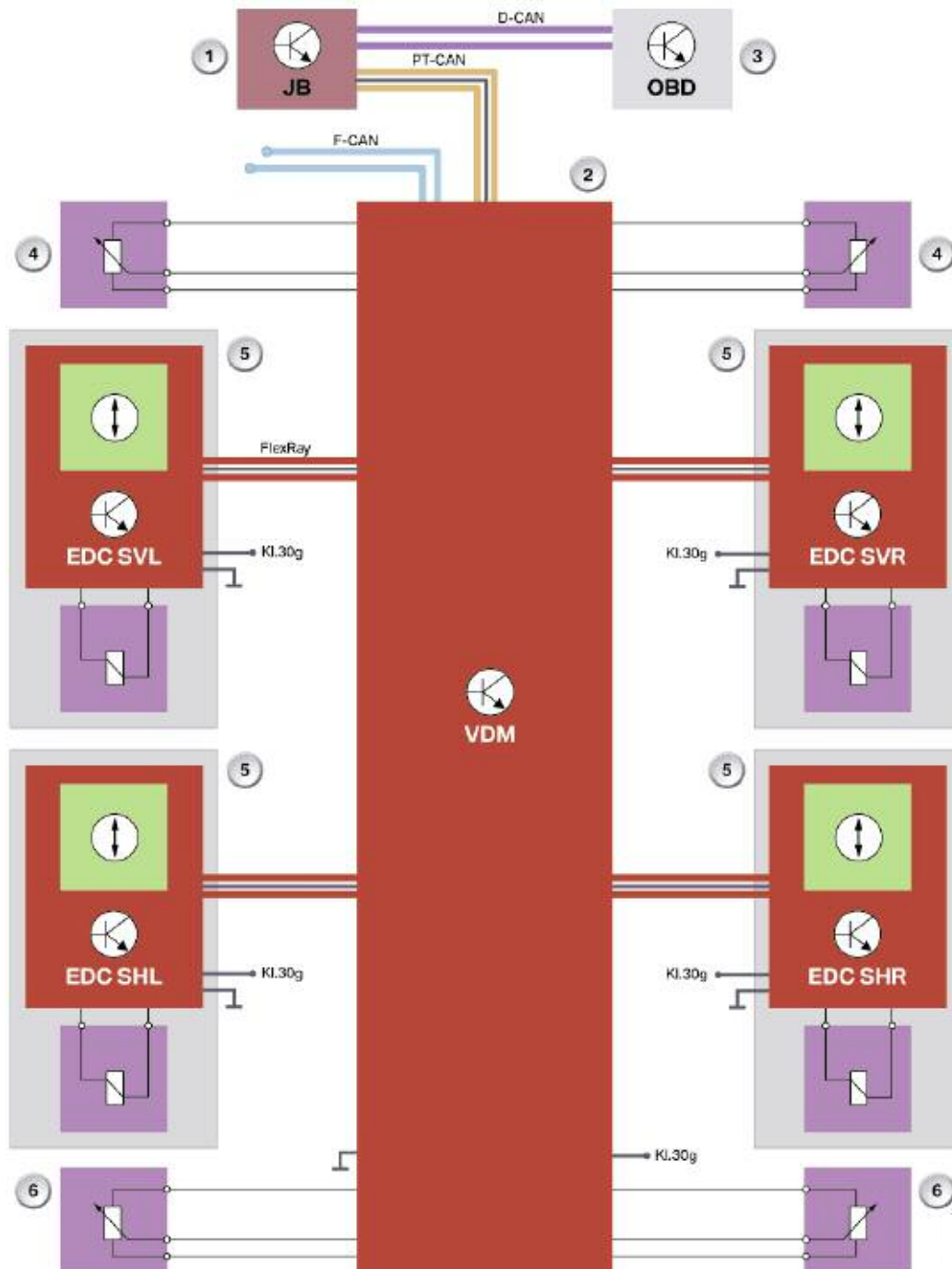
The FlexRay bus system is an industrial standard and is therefore supported and further developed by many manufacturers.



FlexRay in E7x Vehicles

With the launch of the E70, the FlexRay bus system will be used for the first time worldwide in a standard production vehicle. The FlexRay bus system establishes the connection between the VDM control unit (vertical dynamics management) and the EDC satellites at the shock absorbers. A detailed functional description of the overall system can be found in the reference information - "Vertical Dynamics Systems".

E7x FlexRay Bus System Overview



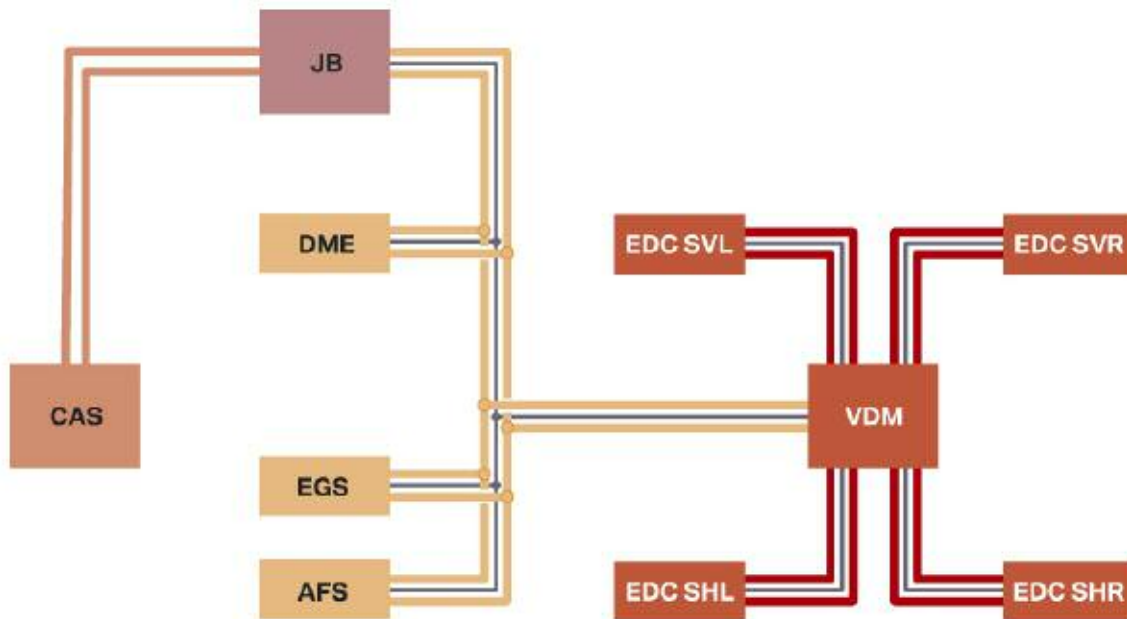
Legend for E7x FlexRay Bus System Overview

Index	Explanation
1	Junction box control unit
2	Vertical Dynamics management (VDM)
3	Diagnosis connector
4	Ride height sensors, front
5	EDC satellites with vertical acceleration sensors and solenoid valves
6	Ride height sensors, rear
D-CAN	Diagnosis CAN
F-CAN	Chassis CAN
PT-CAN	Powertrain CAN
FlexRay	FlexRay bus system
KL 30 g	Terminal 30g

The FlexRay bus system is designed as a two-wire, single-channel bus system. Acting as the gateway, the VDM control unit establishes the connection between the PT-CAN and FlexRay bus systems.

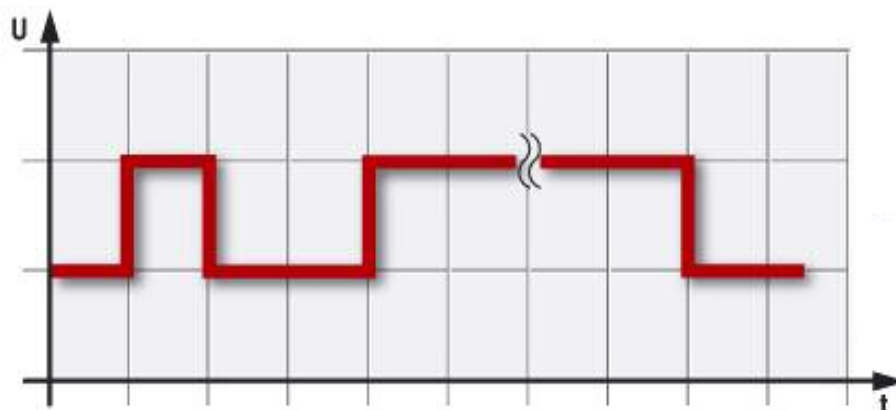
Data communication between the EDC satellites on the FlexRay and the other control units installed in the E70 takes place via the VDM control unit.

■ Wake-up and Sleep Characteristics



The control units are activated by means of an additional wake-up line. The wake-up line has the same function as the previous wake-up line (15WUP) in the PT-CAN. The signal curve corresponds to the signal curve of the PT-CAN.

As soon as the bus system is woken, the VDM receives a High level on the PT-CAN and transfers this signal to the wake-up line of the FlexRay, thus also waking the satellites.



The "wake-up voltage curve" graphic shows the typical behavior of the voltage curve in response to unlocking and starting the vehicle.

Phase 1:

Driver unlocks the car, the CAS control unit activates the K-CAN and the PT-CAN, the voltage level in the PT-CAN briefly goes to High, the VDM copies the signal and transfers it to the wake-up line on the FlexRay.

Phase 2:

Car is opened, terminal R is still OFF, the voltage levels in the bus systems drop again.

Phase 3:

Car is started, terminal 15 is ON, the voltages remain at the set levels until terminal 15 is turned off again.

Phase 4:

The complete vehicle network must assume sleep mode at terminal R OFF in order to avoid unnecessary power consumption. Each control unit in the network signs off to ensure that all control units "are sleeping". Only when all EDC satellites have signed off at the VDM control unit can this control unit pass on this information to the PT-CAN and therefore to the complete network. An error message is stored if this is not the case. This error message is then evaluated as part of the energy diagnosis procedure.

Wiring

The wiring of the FlexRay bus in E7x vehicles is executed as a sheathed, two-core, twisted cable. The sheathing protects the wires from mechanical damage. The terminating resistors are located in the EDC satellites. Each satellite has one terminating resistor. Since the surge impedance (impedance of high-frequency lines) of the lines depends on external influencing factors, the terminating resistors are precisely matched to the required resistance.

The four sections of line to the satellites can be checked relatively easily by means of a resistance measuring instrument (ohmmeter, multimeter). The resistance should be measured from the VDM control unit. See BMW diagnostic system for pin assignments.

The following conclusions can be made:

- RBP-BM: < or = 10 Ω – There is a short circuit in this section of line.
- RBP-BM: 10-90 Ω – This section of line is damaged (e.g. moisture in connector, line pinched)
- RBP-BM: 90-110 Ω – This section of line is **OK** and the satellite is connected (Note: Impedance errors are not recognized)
- RBP-BM: > 110 Ω – There is a break in the line or the satellite is not connected or there is a break in the connection to the satellites.

RBP **Resistance Bus Plus**
BM **Bus Minus**

Plug Connections

The two plug connections contain the power supply of the control units, the wake-up line and the bus connection with wake-up line. The connection to the satellites in the wheel arch is made with waterproof plugs. Two plugs are used:

Plug 1, black	Terminal 30g Terminal 31 Wake-up line
Plug 1, blue	FlexRay (green wire) FlexRay (pink wire)

■ Measurements on the FlexRay

For resistance measurement in the FlexRay, be sure to observe the vehicle wiring diagram!

The various termination options mean that misinterpretations of the measurement results can occur. Measuring the resistance of the FlexRay lines cannot provide a 100% deduction in terms of the system wiring. In the case of damage such as pinching or connector corrosion, the resistance value may be within the tolerance when the system is static.

In dynamic mode, however, electrical influences can cause increased surge resistance, resulting in data transmission problems.

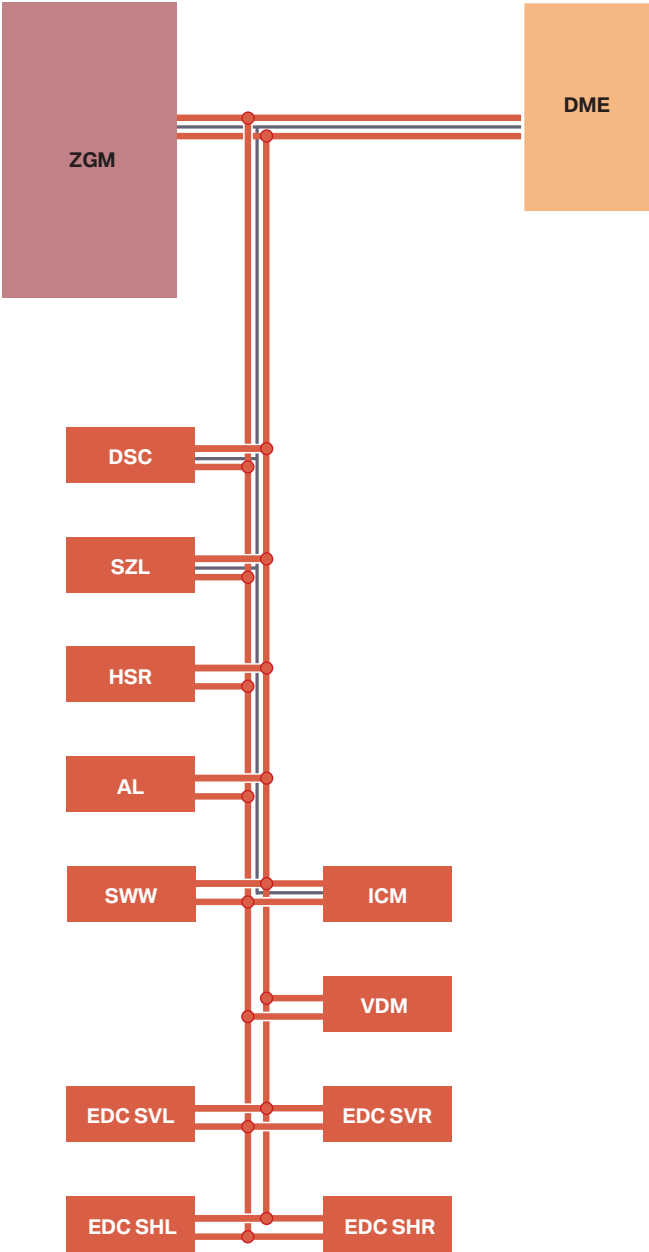
It is possible to repair the FlexRay bus. If damaged, the cables can be connected using conventional cable connectors. Special requirements, however, must be observed when reinstalling the system.

The wiring of the FlexRay system consists of twisted lines. Where possible, this twisting should not be altered during repairs. Repaired areas with stripped insulation must be sealed again with shrink-fit tubing. Moisture can affect the surge resistance and therefore the efficiency of the bus system.

FlexRay - Application in F0x Vehicles

In the F01/F02, the FlexRay bus system was used for the first time across systems to network dynamic driving control systems and the engine management system in a series vehicle. The central gateway module sets up the link between the various bus systems and the FlexRay.

FlexRay - simplified view



Properties of FlexRay

The most important properties of the FlexRay bus system are outlined in the following:

- Bus topology
- Transmission medium - signal properties
- Deterministic data transmission
- Bus protocol

■ Bus Topology

The FlexRay bus system can be integrated in various topologies and versions in the vehicle.

The following topologies can be used:

- Line-based bus topology
- Point-to-point bus topology
- Mixed bus topology

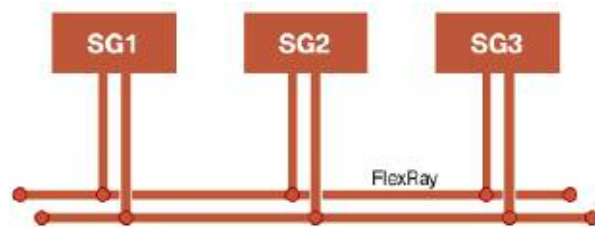
Line-based Bus Topology

All control units (SG1...SG3) in line-based topology are connected by means of a two-wire bus, consisting of two twisted copper cores. This type of connection is also used on the CAN-Bus. The same information but with different voltage level is sent on both lines.

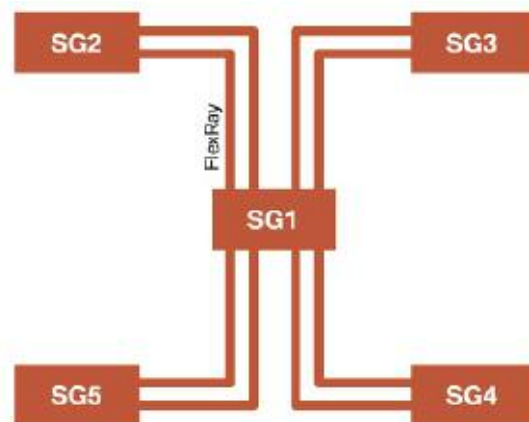
The transmitted differential signal is immune to interference. The line-based topology is suitable only for electrical data transmission.

Point-to-point Bus Topology

The satellites (control units SG2...SG5) in point-to-point bus topology are each connected by a separate line to the central master control unit (SG1). Point-to-point topology is suitable for both electrical as well as optical data transmission.



Line-based bus topology



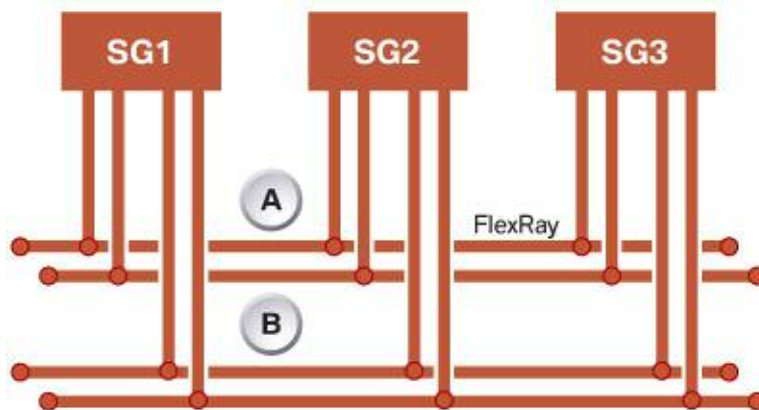
Point to point bus topology

Mixed Bus Topology

Mixed bus topology caters for the use of different topologies in one bus system. Parts of the bus system are line-based while other parts are point-to-point.

Redundant Data Transmission

Fault-tolerant systems must ensure continued reliable data transmission even after failure of a bus line. This requirement is realized by way of redundant data transmission on a second data channel.



Index	Explanation
A	Channel 1
B	Channel 2

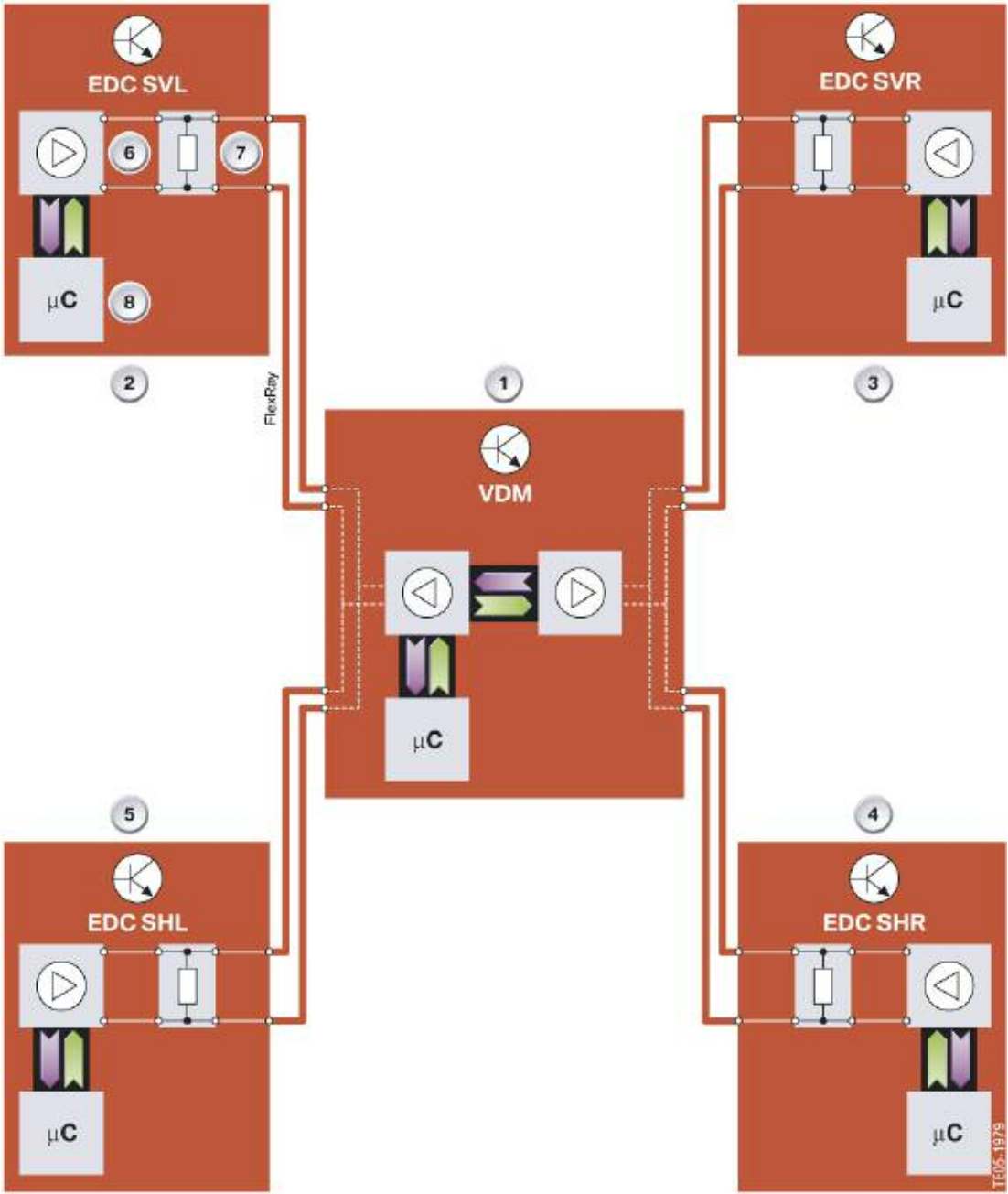
A bus system with redundant data transmission uses two independent channels. Each channel consists of a two-wire connection. In the event of one channel failing, the information of the defective channel can be transmitted on the intact channel. FlexRay enables the use of mixed topologies also in connection with redundant data transmission.

Bus Topology of FlexRay in E7x Vehicles

The physical configuration of the FlexRay bus system in E7x vehicles is point-to-point. All EDC satellites are individually connected via plug connections to the VDM control unit.

Internally, however, the left and right EDC satellites are connected to form a line-based topology. The two lines are connected by means of a double point-to-point connection consisting of two bus drivers. Every item of information that is sent from one of the EDC satellites or from the central VDM control unit reaches all connected control units.

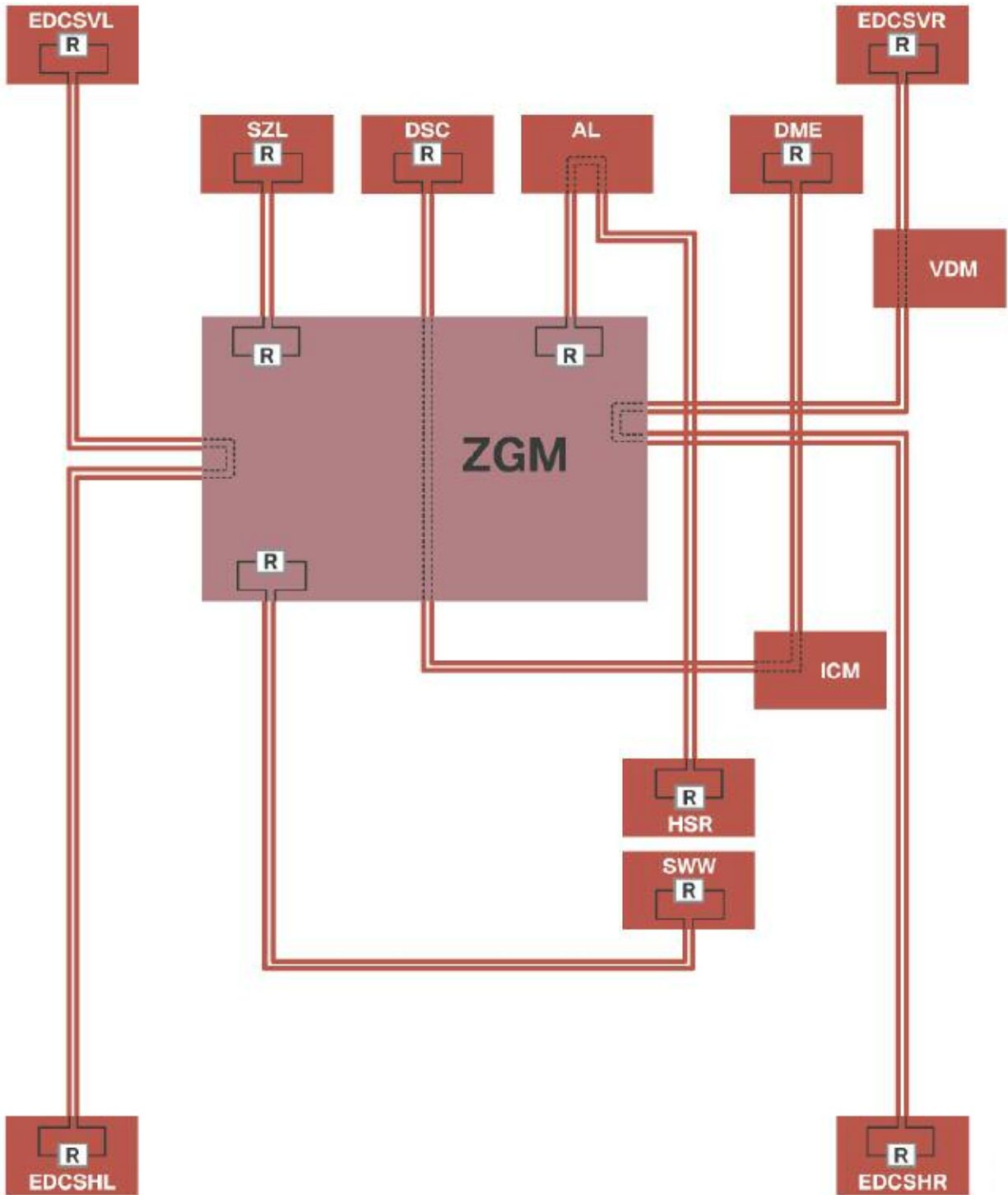
VDM System Schematic on E7x Vehicles



Index	Explanation	Index	Explanation
1	Vertical Dynamics Management (VDM)	6	Bus driver
2	EDS satellites, front left	7	Terminating resistor
3	EDS satellites, front right	8	Microprocessor
4	EDS satellites, rear right	FlexRay	FlexRay bus system
5	EDS satellites, rear left		

FlexRay Bus Topology on F0x Vehicles

Physical structure of FlexRay F0x (topology)



Legend for Physical structure of FlexRay F0x (topology)

Index	Explanation
AL	Active steering system
BD	Bus driver
DM	Digital Motor Electronics
DSC	Dynamic Stability Control
EDCSH	Electronic damper control, rear left satellite
EDCSHR	Electronic damper control, rear right satellite
EDCSVL	Electronic damper control, front left satellite
EDCSVR	Electronic damper control, front right satellite
HSR	Rear-axle drift angle control
ICM	Integrated Chassis Management
SZL	Steering column switch cluster
VDM	Vertical dynamics management
ZGM	Central gateway module

FlexRay Bus Topology on the F01

The FlexRay is always shown in a simplified form in the overview of the bus systems. The actual topology of the FlexRay as used in F0x vehicles is shown in the preceding graphic.

Depending on the level of equipment of the vehicle, the ZGM contains one or two so-called star couplers, each with four bus drivers. The bus drivers forward the data of the control units via the communication controller to the central gateway module (ZGM). Depending on the type of termination the FlexRay control units have, they are connected to these bus drivers in two different ways.

Note: For further information regarding the FlexRay refer to the F01 training information available on TIS and ICP.

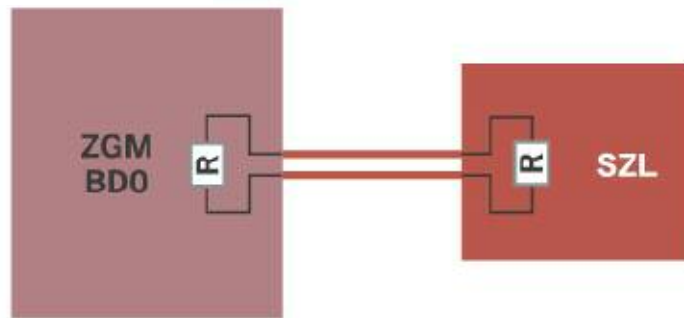
■ Bus Termination

In the same way as most bus systems, resistors for termination (as bus termination) are also used at both ends of the data lines on the FlexRay to prevent reflections on the lines.

The value of these terminal resistors is determined from the data transfer rate and cable lengths. The terminal resistors are located in the control units.

If only one control unit is connected to a bus driver (e.g. SZL to the bus driver BD0), the connections on the bus driver and on the control unit are fitted with a terminal resistor.

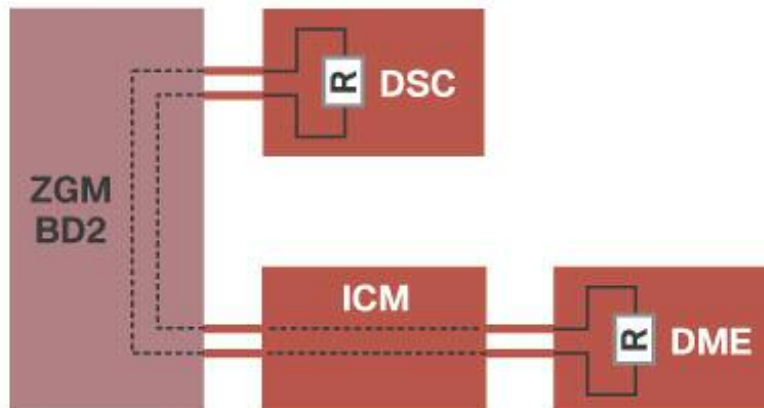
Terminal resistor



This type of connection at the central gateway module is called "end node termination".

If the connection at the control unit is not the physical finish node (e.g. DSC, ICM and DME at the bus driver BD2), it is referred to as a FlexRay transmission and forwarding line. In this case, both components must be terminated at the ends of each bus path with terminal resistors.

Through-looped FlexRay



This connection option exists for the central gateway module and a number of control units. However, the control unit with a transmission and forwarding line has a 'non-end node termination' for data pickup. This type of termination cannot be tested using measurement systems at the control unit connector due to its resistor / capacitor circuit.

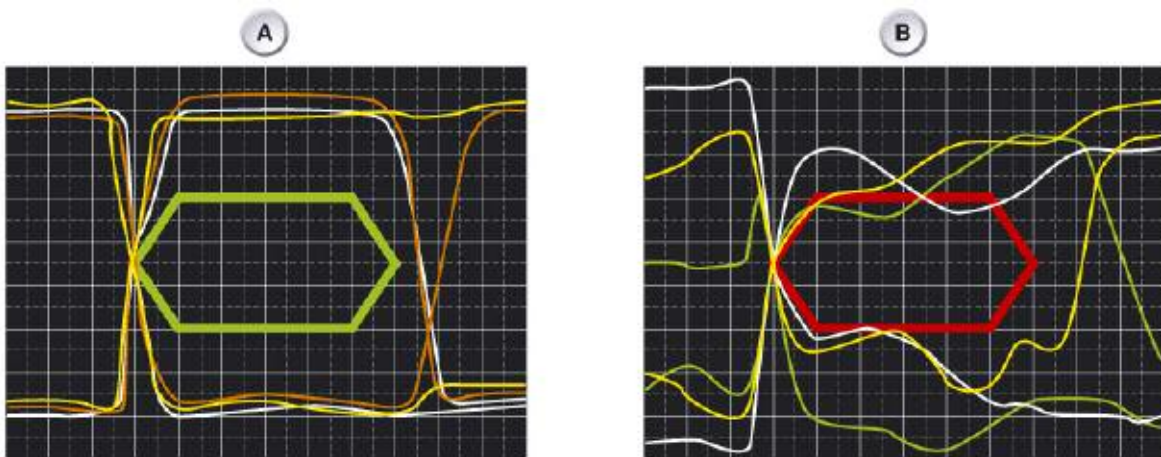
To measure the (current-free) FlexRay bus to determine the line or terminating resistance, please be sure to use the vehicle wiring diagram.

■ Transmission Medium - Signal Properties

The bus signal of the FlexRay must be within defined limits. A good and bad image of the bus signal is depicted below. The electrical signal must not enter the inner area neither on the time axis nor on the voltage axis. The FlexRay bus system is a bus system with a high data transmission rate and therefore with rapid changes in the voltage level.

The voltage level as well as the rise and drop of the voltage (edge steepness) are precisely defined and must be within certain values. There must be no infringements of the marked "fields" (green and red hexagon).

Electrical faults resulting from incorrect cable installation, contact resistance etc. can cause data transmission problems.



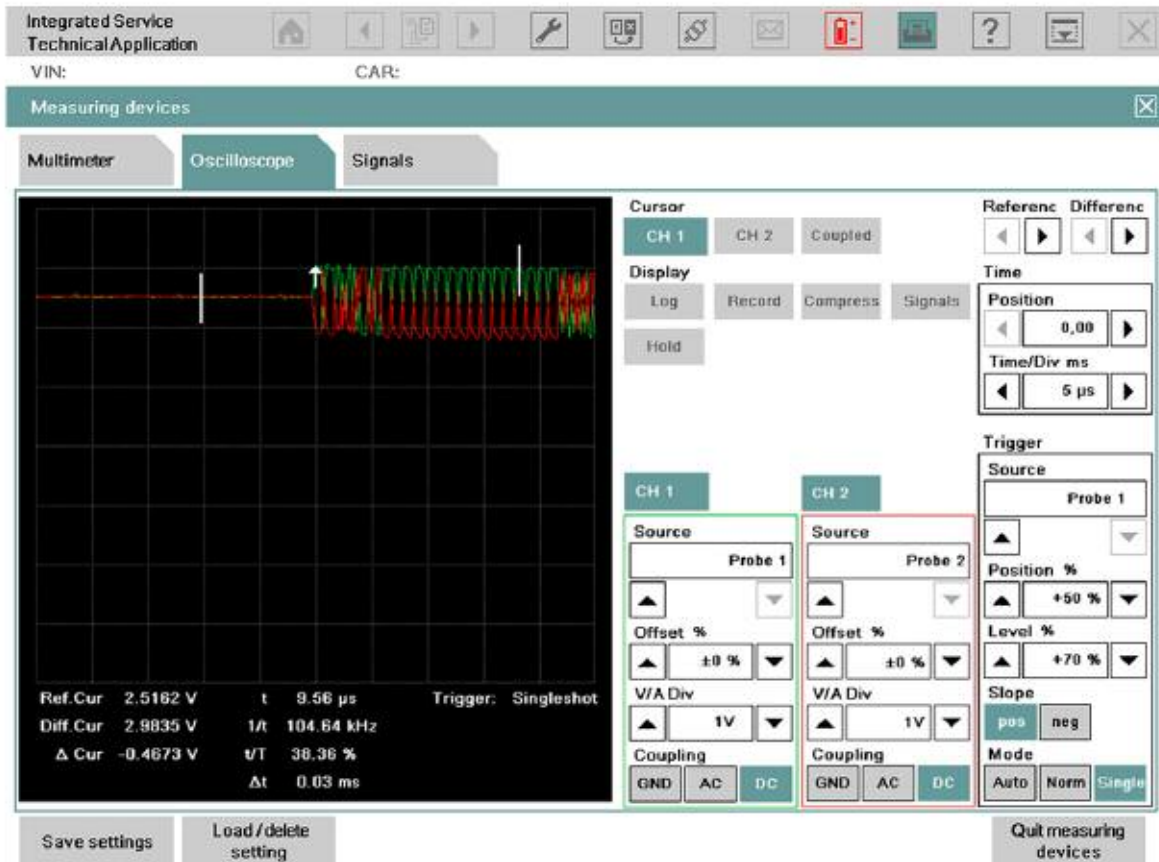
Index	Explanation	Index	Explanation
A	Good image	B	Bad image

The images shown above can be depicted only with very fast oscilloscopes. The oscilloscope in the BMW diagnostic system is not suitable for representing such images.

The voltage ranges of the FlexRay bus system are:

- System ON - no bus communication 2.5 V
- High signal - 3.1 V (voltage signal rises by 600 mV)
- Low signal - 1.9 V (voltage signal falls by 600 mV)

The voltage values are measured with respect to ground.



Scope settings to test the FlexRay:

CH1: Test probe 1, range 1 V/Div; DC coupling

CH2: Test probe 2, range 1 V/Div; DC coupling

Time: 5 μS/div

Workshop Hint

As of ISTA v2.24.2 the RECORD button becomes unavailable if the Time/Div is < 2ms, however if you press the HOLD button and then press it again, the RECORD button becomes available for a short period of time.

Deterministic Data Transmission

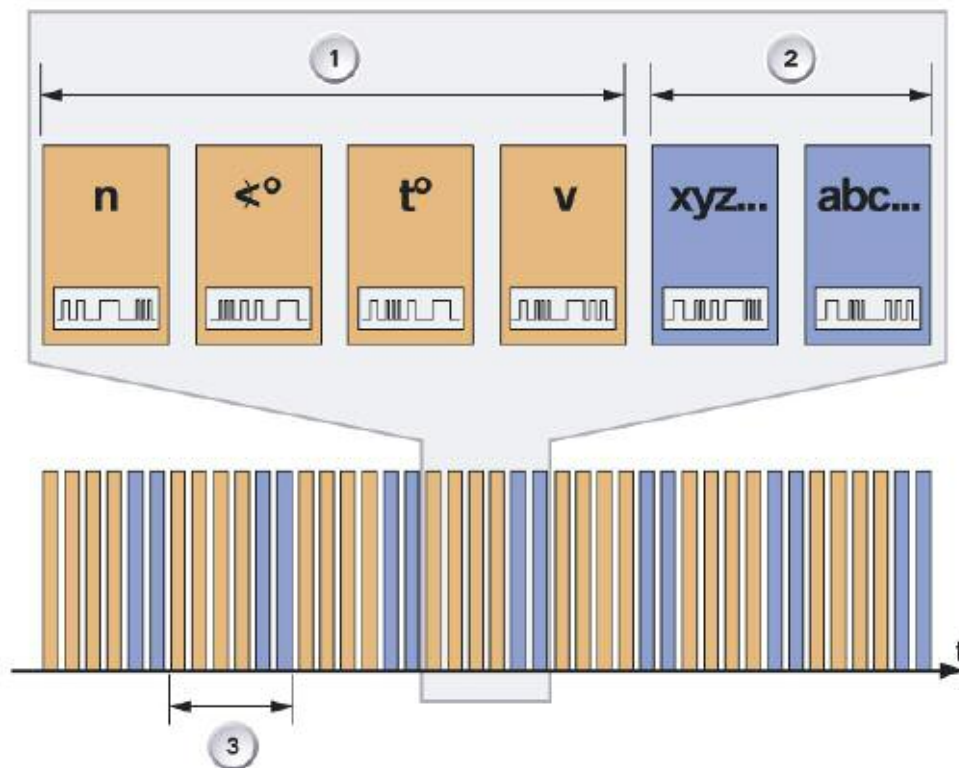
The CAN-Bus system is an event-controlled bus system. Data are transmitted when an event occurs. In the event of an accumulation of events, delays may occur before further information can be sent. If an item of information cannot be sent successfully and free of errors, this information is continually sent until the communication partner confirms its receipt.

If faults occur in the bus system, this “event controlled” information can back up causing the bus system to overload, i.e. there is a significant delay in the transmission of individual signals. This can result in poor control characteristics of individual systems.

The FlexRay bus system is a time-controlled bus system that additionally provides the option of transmitting sections of the data transmission event-controlled. In the time controlled part, time slots are assigned to certain items of information. One time slot is a defined period of time that is kept free for a specific item of information (e.g. engine speed).

Consequently, important periodic information is transmitted at a fixed time interval in the FlexRay bus system so that the system cannot be overloaded.

Other less time-critical messages are transmitted in the event-controlled part. An example of deterministic data transmission is outlined in the following.



Index	Explanation
1	Time-controlled part of cyclic data transmission
2	Event-controlled part of cyclic data transmission
3	Cycle (5 ms total cycle length of which 3 ms static (= time-controlled) and 2 ms dynamic (= event-controlled))
n	Engine speed
<	Angle
t	Temperature
v	Road speed
xyz..abc..	Event-controlled information
t	Time

■ Bus Protocol

Deterministic data transmission ensures that each message in the time-controlled part is transmitted in real time. Real time means that the transmission takes place within a defined time.

Therefore, important bus messages are not sent too late due to overloading of the bus system. If lost due to a temporary problem in the bus system (e.g. EMC problem) a message cannot be sent again. A current value is sent in the next assigned time slot.

■ High Bandwidth

The FlexRay bus system operates with a data transmission rate of 10 Mbits/s. This speed corresponds to 20 times the data transmission rate of the PT-CAN.

■ Synchronization

A common time base is necessary in order to ensure synchronous execution of individual functions in interconnected control units. Time matching must take place via the bus system as all control units operate with their own clock generator.

The control units measure the time of certain synchronization bits, calculate the mean value and adapt their bus clock to this value. This system ensures that even minimal time differences do not cause transmission errors in the long term.

Ethernet - Faster Programming Access

Ethernet in F0x Vehicles

Ethernet is a manufacturer-neutral, cable-bound network technology. Most computer networks nowadays are based on this data transfer technology.

The so-called Ethernet was developed more than 30 years ago. Since then, the data transfer rates have multiplied. The IEEE 802.3u specification with 100 MBit/s data transfer rate is used in F0x vehicles. The IEEE 802.3xx is a standard for cable-bound networks of the Institute of Electrical and Electronic Engineers. This specification is also known as "Fast Ethernet".

The transfer protocols are the protocols TCP/IP (Transmission Control Protocol/ Internet Protocol) and UDP (User Datagram Protocol).

■ Application

The Ethernet in the diagnosis socket is only enabled when the BMW programming system (ICOM A) is connected. There is an activation bridge in the programming connector, between pins 8 and 16. This switches the power supply for the Ethernet controller in the central gateway module.

This means that Ethernet access to the central gateway module is disabled while the vehicle is being driven by the customer. The Ethernet connection between the information and communications systems is permanently enabled in the diagnosis socket independently of the activation bridge.

■ Security

Each participant in an Ethernet has an individually assigned identification number, an MAC address (Media Access Control). This address and the VIN (Vehicle Identification Number) identifies the vehicle to the BMW programming system on connection setup. This prevents changes to the data records and stored values by third parties.

In the same way as in a computer network in the office, each device in a network must receive unique identification. This is why the central gateway module is assigned a so-called IP address by the programming system after connection setup.

The function of an IP address in a network corresponds to that of a telephone number in the telephone network. This IP address is assigned per DHCP (Dynamic Host Configuration Protocol). This is a method of automatic allocation for IP addresses to user devices in a network.

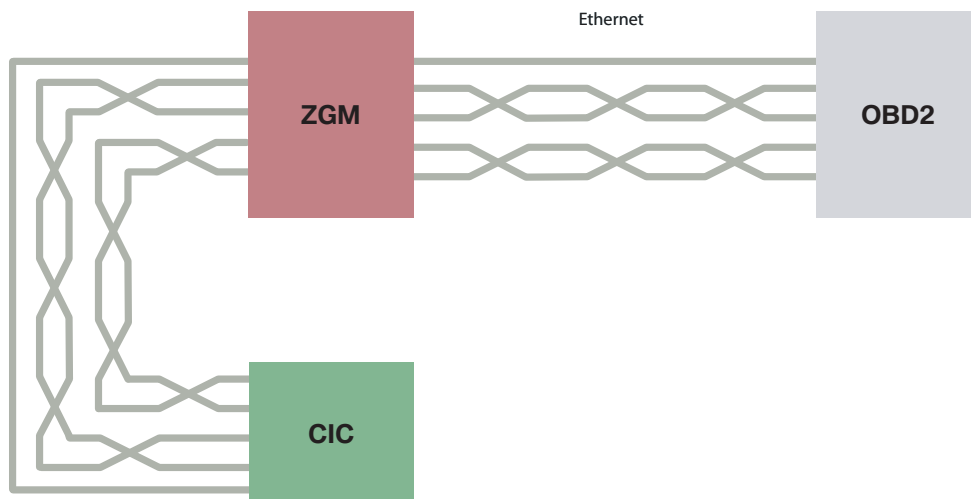
■ Features of Ethernet

- Very high data rate of 100 MBit/s.
- System start time with connection setup and address assignment under three seconds, sleeping under one second.
- System access only via BMW programming systems.

■ Functions of Ethernet

- Faster programming of the vehicle in Service.

Ethernet



Index	Explanation	Index	Explanation
ZGM	Central gateway module	OBD2	Diagnosis socket
CIC	Central information computer		

The wiring between the diagnosis socket and ZGM is with two pairs of wires without additional shielding. There is also an activating line that supplies the Ethernet controllers in the control units with voltage.

There is a Cat5 cable between the diagnosis connector and the BMW programming system. These Cat5 cables are network cables with four twisted, unshielded pairs of wires that are approved for signal transfers at up to 100 MHz operating frequency. However, two pairs of wires are sufficient for the transfer capacity required in the F01/F02.

Fiber Optic Bus Networks

The ever-increasing level of features available in today's automobiles require a corresponding increase in vehicle electronic systems. The transmission of data, voice and images require an efficient method to move data.

Copper wire bus networks offer many advantages. However high data transmission rates in copper wires can cause electro-magnetic interference with other vehicle systems.

Compared with copper wires, fiber optic lines require less space and are lighter in weight for the same transmission band width. In contrast with copper wires, which carry digital or analog voltage signals as the means of transmitting data, fiber optic busses transmit light pulses.

Fiber Optic technology has been in use in the telecommunications industry for many years. However, this type of fiber-optic cable is not practical for automotive use. These cable utilize glass based fibers which are not practical for automotive use. They are subject to fracture from vibration and do not hold up to "tight radius" installations.

POF (polymer optical fibers) were developed for the automotive industry. These fibers were developed and manufactured by Dow-Corning.

The most commonly used fiber optics conductors are:

- Plastic fiber optics conductors
- Glass fiber optics conductors

Only plastic fiber optics conductors are used in BMW vehicles.

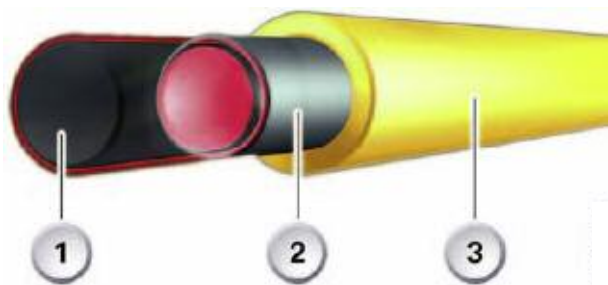
There are significant advantage to using POF fiber optic cables:

- There is a low sensitivity to dust. Small amounts of contamination do not adversely affect communication.
- They are easy to work with. These fibers can be bent to a radius of approximately 50mm. This allows for practical installation within the vehicle.
- Processing is practical, these fibers can be cut and modified which makes the production of wiring looms easy. Service repairs are also made simple.
- These fibers are inexpensive to manufacture and do not require expensive connections or housings.
- Fiber optic cables are imperious to EMF (Electromotive Interference).

Design

A fiber optics conductor is a thin cylindrical fiber made of plastic which is enclosed by a thin sheathing or jacketing. The actual fiber optics conductor is embedded in the sheathing material that serves the purpose of protecting the actual fibers.

Structure of a fiber optics conductor

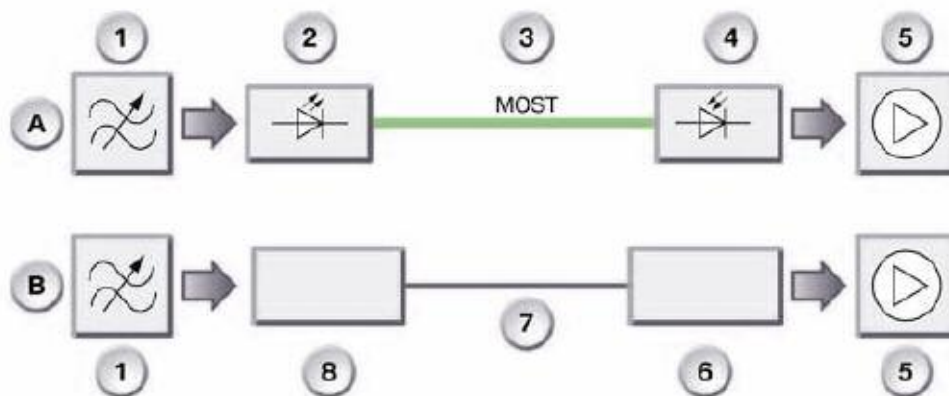


Index	Explanation
1	Fiber Core
2	Sheathing
3	Padding

Principle of Optical Transmission

In principle, any system that transmits electrical signals with the aid of light beams (luminous radiation) consists of the components shown in the following illustration. The signal controls a light (radiation) source such that the radiation intensity of this source is proportional to the time fluctuations of the signals.

Parallels can be drawn when comparing an optical message system with a modem transmission system (computer - internet):



Index	Explanation	Index	Explanation
A	Optical transmission	4	Photodiode (Receiver)
B	Electrical transmission	5	Receiver
1	Source	6	Demodulator (Receiver in modem)
2	Light-emitting diode (Transmit diode)	7	Cable
3	Headrest guide	8	Modulator (Transmitter in modem)

The fiber optics conductor assumes the function of the transmission channel. The fiber optics conductor is particularly insensitive to external electromagnetic influences.

Comparison of an optical message transmission system with a conventional message system.

Modem transmission:

As part of modem transmission, the modulator, the transmit part of the modem, converts the digital signals into analog signals. The analog signals are transmitted via the telephone network to the next computer.

The demodulator, the receive part of the modem, at this computer converts the analog signals back to digital signals.

Optical transmission:

With optical message transmission, on the other hand, the digital signals are converted into optical signals by means of a light emitting diode (LED).

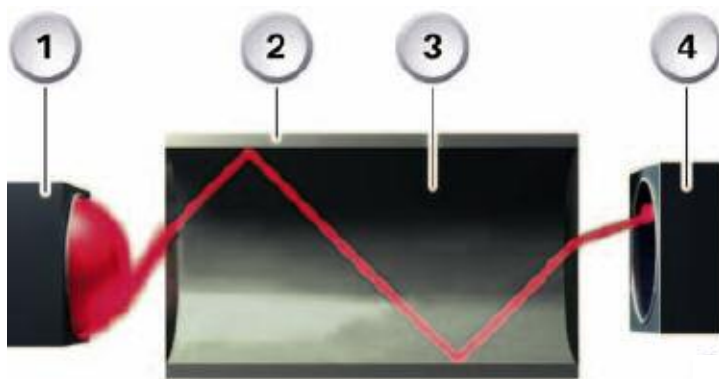
The optical signals are transmitted via fiber optics conductors to the next control unit.

The photodiode at this control unit converts the optical signals back to digital signals.

Principle of Light Transmission

The electrical signal generated by the control unit is converted to an optical signal by an internal transmitter module and sent along the fiber optic bus. The fiber core carries the light beam to a receiver module which converts the light signal back to a useable electrical signal.

The light therefore passes through the fiber optics conductor. The light is then converted back to an electrical signal with the aid of a receiver component.

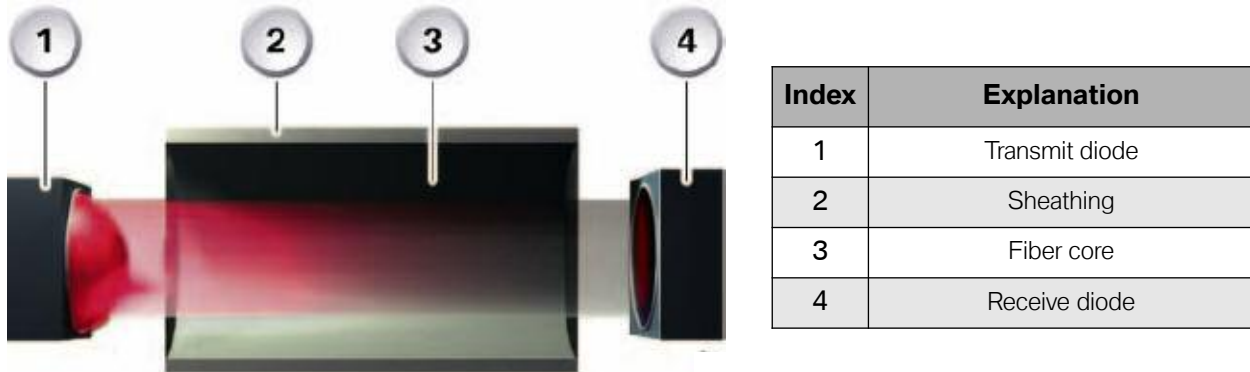


Index	Explanation
1	Transmit diode
2	Sheathing
3	Fiber core
4	Receive diode

Principle of data transmission with light

Light Attenuation

Attenuation refers to the reduction in strength of a signal. Light transmitted along the optical fiber becomes weaker the further it has to travel. This effect is known as attenuation. This attenuation is comparable to the electrical resistance of a copper wire. Attenuation is usually measured in decibel units (dB). In fiber optic cables, attenuation is measured in terms of the number of decibels per unit of length (foot/meter etc). The less attenuation per unit distance, the more efficient the cable.



Attenuation of the light within a fiber optics conductor

In comparison with an electrical circuit, think of attenuation as “light resistance”. The more attenuation in the fiber optic cable, the less light output to the receiver module.

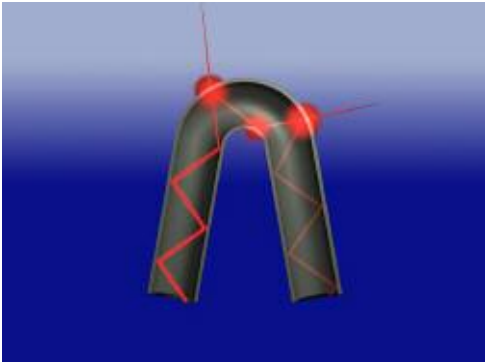
The average attenuation for fiber optic bus lines is .5 decibels (dB) for each connector and .3 dB for each meter of cable.

■ Causes of Excessive Attenuation

Excessive attenuation can be caused by the following reasons:

- Bends in the fiber optic cable with a radius of less than 50mm.
- Kinks in the fiber optic cable
- Squashed or compressed fiber optic cable
- Damaged insulation on fiber optic cable
- Stretched fiber optic cable
- Dirt or grease on the exposed cable ends
- Scratches on the exposed cable ends
- Overheated fiber optic cable

Here are some examples of various fiber optic cable failures:

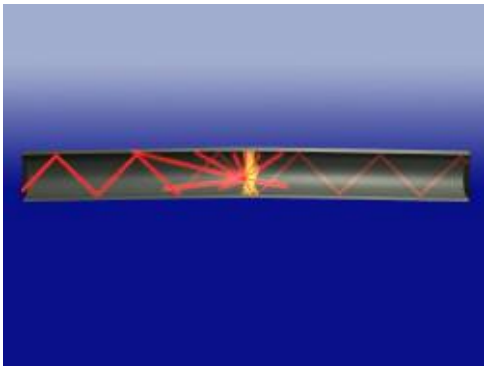


Bending Radius

The plastic fiber optic cable should not be bent to a radius of less than 50mm.

That is roughly equivalent to the diameter of a soft-drink can. Bending the cable any tighter can impair its function or irreparably damage the cable.

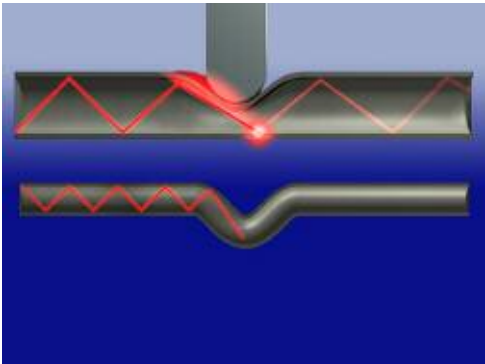
Light can escape at points where the cable is bent too tightly. This is caused by the fact that the light beam strikes the interface between the core and cladding at too steep an angle and is not reflected.



Kinking

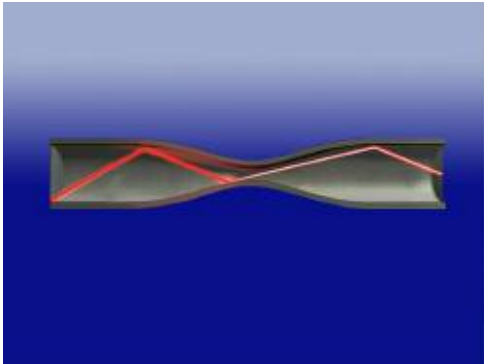
Fiber optic cables must not under any circumstances be kinked when fitted because this damages the cladding and the fiber core. The light is partially dispersed at the point where the fiber is kinked and transmission loss results.

Even just kinking the cable once very briefly is enough to cause permanent damage.



Compression Points

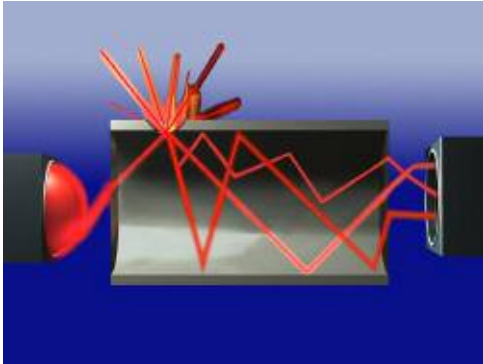
Compression points must also be avoided because they can permanently deform the light conducting cross section of the optical fiber. This would cause a loss of light.



Stretching

Overstretching of the fiber optic cables, caused by pulling for example, can destroy them.

Stretching reduces the cross-sectional area of the fiber core. Restricted passage of light is the end result.

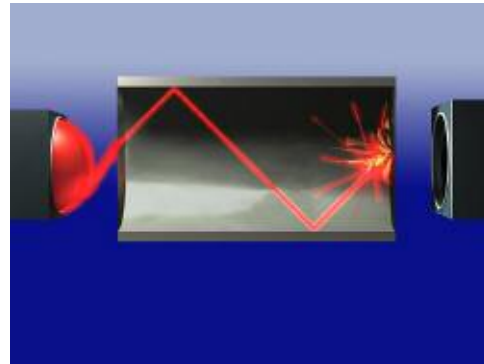


Abrasion Points

In comparison with copper wires, abrasion of fiber optic cables does not cause a short circuit.

Instead, loss of external light occurs.

The system then suffers interference or fails completely.



Dirty or Scratched Fiber Optic Cable Ends

Another potential source of problems is dirty or scratched cable ends. Although the ends of the cables are protected against accidental contact, damage can still occur by incorrect handling.

Dirt on the end of an optical fiber will prevent light from exiting/entering. The dirt absorbs the light and increases attenuation.

Service Considerations

Two optical bus systems for data transmission have been developed for BMW vehicles: MOST and *byteflight*.

The light length is 650 nm (red light).

Three different colors are used to differentiate between the fiber optics conductors for the different bus systems:

- Yellow: *byteflight*
- Green: MOST
- Orange: Service repair line

During repair work, there are some things that need to be taken into account when working with fiber optic cables. Any paintwork which requires the use of drying by heat, the temperature should not exceed 85°C. This could cause deformation of the fiber optic cable resulting in excessive attenuation.

Extreme care should be taken around fiber optic cables. Any wiring harness that contain fiber optic cables should not be subjected to stretching, pulling or any undue stress.

■ Cable Repair

Repair cable are available for the fiber optics. The MOST bus which is normally green in the vehicle is repair using a black or orange cable. The MOST bus allows for up to one splice between control units.

Special crimping pliers are used to fit the sleeves correctly on the fiber optics conductors.

The exact procedure is described in the operating instructions for the crimping pliers.

The *byteflight* which is a safety critical network does not allow for any splices or repairs between control units. The entire defective optical cable must be replaced.

Replacement cables are orange or black.



The fiber optics conductors in the *byteflight* system can NOT be repaired. In contrast to the MOST bus which allows one (1) splice between controllers (when using the proper part #) a defective *byteflight* cable between controllers MUST be completely replaced.

■ Fiber Optic Connectors

There are slight differences between the connectors on the MOST and *byteflight* bus. The transmitter/receiver module on the MOST bus are set back into the control unit housing. This setup allows for the protection of the delicate fiber ends of the cable. Also, MOST cable connectors are marked 1 and 2. 1 is assigned to the incoming optical fiber and 2 is assigned to the outgoing optical fiber (see connection of control units for more information).

Note: Refer to the MOST Bus Diagnosis section in this training material for more information.

MOST

MOST is a communications technology for multimedia applications that was specially developed for use in motor vehicles.

MOST stands for Media Oriented System Transport. The MOST bus is designed as an optical ring and uses light pulses for transmitting data.

MOST technology satisfies two important requirements:

1. The MOST bus can transfer control, audio and navigation data.
2. The MOST technology makes available a logic frame model for controlling the great variety and complexity of the data.

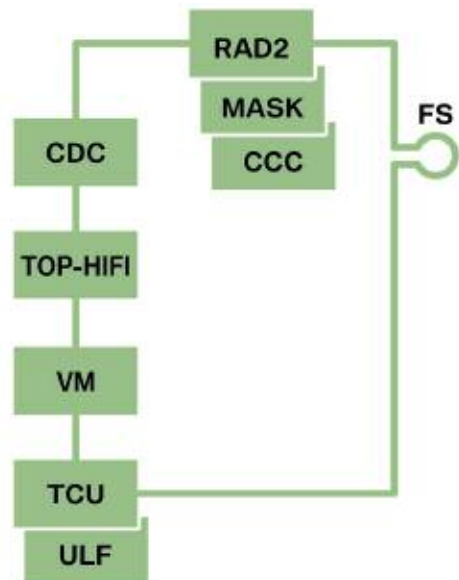
Multimedia components such as:

- Telephone
- Radio
- Television
- Navigation system
- CD changer
- Amplifier
- Multi-information display/on-board monitor

The new logic interconnection and networking of the components gives rise to an enormous increase in system complexity. Since this new dimension of system complexity can no longer be managed with the familiar bus systems, a new bus technology is required: MOST.

The MOST bus is designed as a ring structure and uses light pulses for transmitting data. Data transmission takes place only in one direction. Fiber optics conductors are used as the data transmission medium.

E90 MOST



MOST Design

The MOST bus is designed as a ring structure and uses light pulses for transmitting data. Data transmission takes place only in one direction.

MOST combines the individual components to form one central unit.

As a result, the components interact to a greater extent. The plug&play principle enables simple system expansion with individual components.

MOST is capable of controlling function that are distributed in the vehicle and to manage them dynamically.

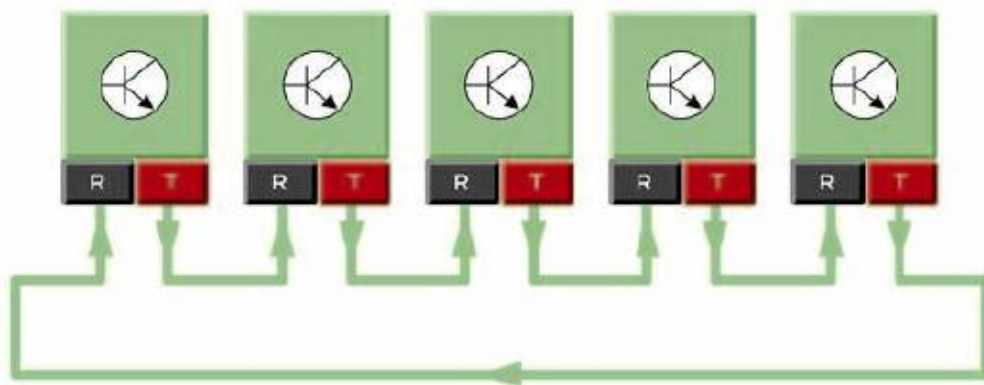
An important feature of a multimedia network is that it not only transports control data and sensor data.

Features

- High data rates: 22.5 Mbits/s
- Synchronous/asynchronous data transmission
- MOST assigns the control units nodes in the bus
- Fiber optics conductors as data transmission medium
- Ring structure

The MOST not only represents a network in the conventional sense but it also provides integrated technology for multimedia and network control.

Ring structure of a network



Index	Explanation
T	Transmitter (Pin 1)
R	Receiver (Pin 2)

■ Ring Structure

Each terminal device (node, control unit) in a network with a ring structure is connected by means of a cable ring.

A message indicating that transmission is possible circulates on the ring. This message is read and passed on by each node (control unit).

When a node wishes to send data, it changes the ready-to-send message to an "occupied" message. It then adds the address of the receiver, an error handling code and the data.

To ensure the signal strength is retained, the node, through which the data package passes through, generates the data once again (repeater).

The node that is addressed as the receiver copies the data and forwards them in the circuit. If the data reach the transmitter again, it removes the data from the ring and resets the ready-to-transmit message.

Specifically: The physical light direction runs from the master control unit (e.g. multi-audio system controller) to the fiber optics conductor connector and from here to the control units (e.g. CD-changer in the luggage compartment). The light then returns from the last control unit back via the flash connector to the master.

Advantages:

- Distributed control
- Large network expansion

Disadvantages:

- Intricate troubleshooting
- Malfunctions cause network failure
- Intricate and extensive wiring

Each MOST control unit can send data on the MOST bus. Only the master control unit can initiate data exchange between the MOST bus and other bus systems.

In order to meet the various requirements of the different data transmission applications, each MOST message is divided into 3 parts:

- Control data: e.g. light intensity (luminosity) control
- Asynchronous data: e.g. navigation system, vector representation
- Synchronous data: e.g. audio and video signals

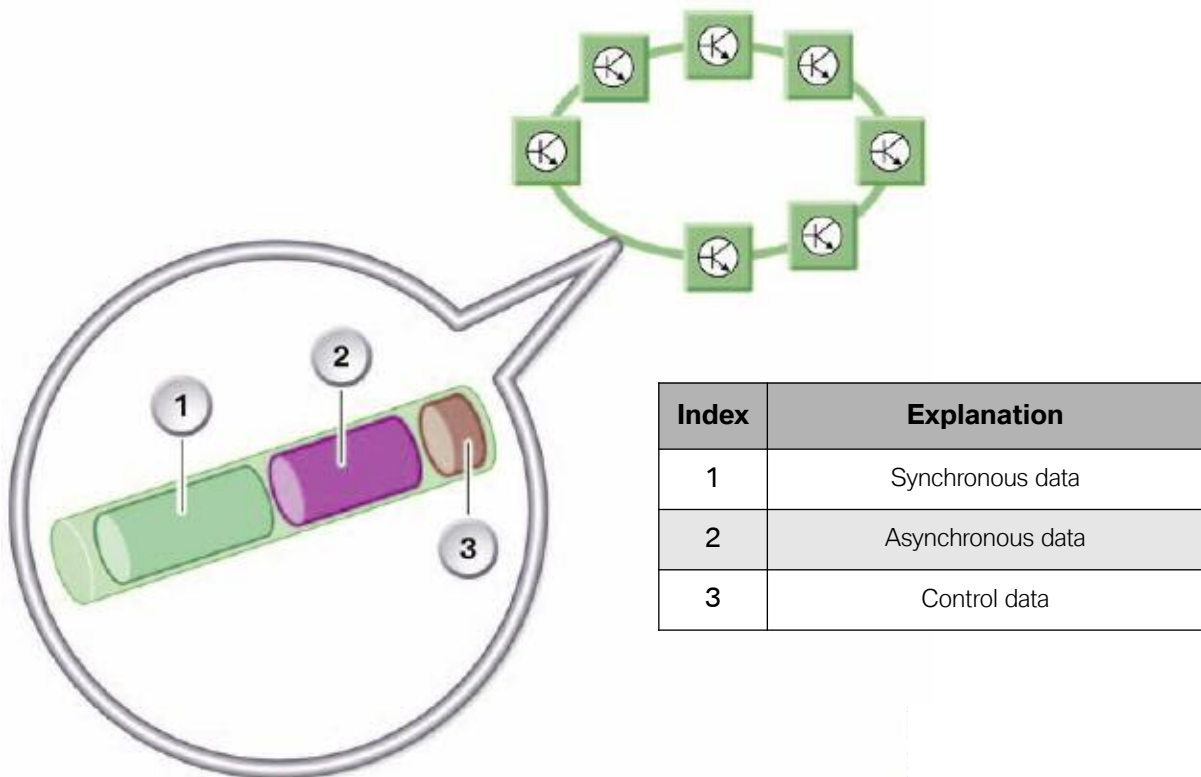
The MOST bus has a ring structure. The various channels (synchronous channel, asynchronous channel and control channel) are transmitted synchronously on a medium. The data are available in the entire ring, i.e. the data are read non-destructively (copied) and can therefore be used by the various components.

The structure of the MOST bus enables easy expansion of the system with further components. The installation location of the components in the ring depends on the specific function. There is no need to operate a reserve for future systems (e.g. double coil speakers).

The receiver and transmitter are connected with each other in the event of a component failing. The ring therefore remains operative. The receiver and transmitter are separated only if one control unit is supplied with power. These two units are completely operative together with the transmit and receive system.

NetService disassembles the data packages in individual parts and reassembles them.

The receiver and transmitter are a BMW development in co-operation with Infineon and Oasis. The information is transmitted by light pulses with a wave length of 650 nm (visible red light). No laser but rather an LED is used to generate the light. The bus can be woken optically, i.e. an additional wake-up line is not required. The power intake in sleep mode is very low.



Data transmission on the MOST-bus

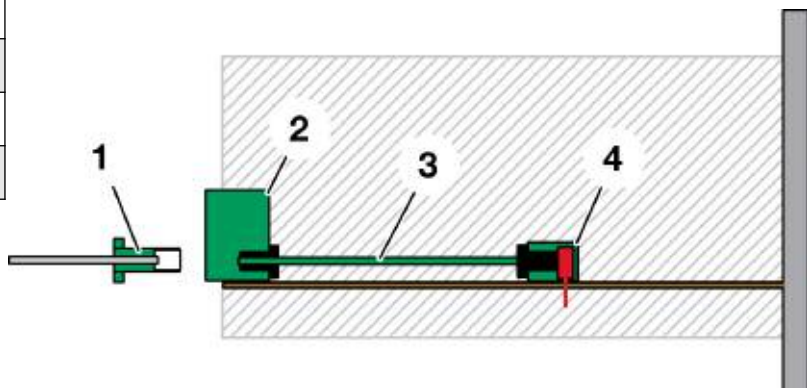
Connection of Control Units

The connection between the individual control units is provided by a ring bus that transports the data only in one direction. This means that a control unit always has two fiber optics conductors, i.e. one for the transmitter and one for the receiver.

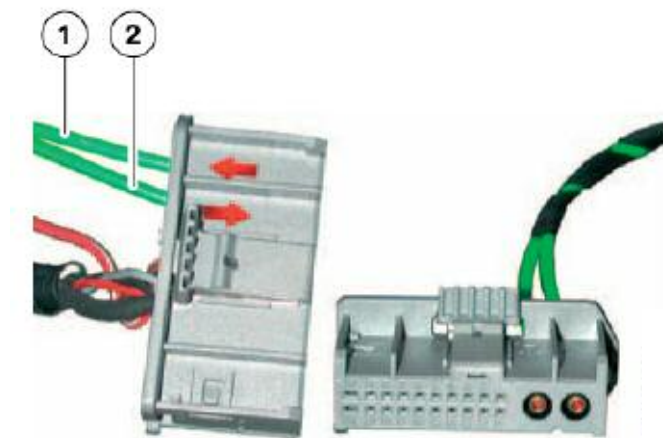
A pure fiber coupling is used in MOST control units. In this way, together with the fibers in the control unit, the transmit and receive diodes can be positioned at any point in the control unit. As a result, the fiber areas can be set back in the wiring harness connector, thus rendering additional protection for the sensitive end faces unnecessary.

The 2-pole fiber optics conductor module is identical for all types of connector. The parts family and contact parts have been declared as the standard within the MOST cooperation.

Index	Explanation
1	Fiber optic connector
2	Control unit socket
3	Fiber optic jumper
4	Receiver module with diode



Connector for fiber optics conductor



Index	Explanation
1	Pin 2
2	Pin 1



Pin 1 is always designated for the incoming fiber optics conductor and pin 2 for the transfer fiber optics conductor.

Fiber Optic Connector

The use of the fiber optic connector provides the advantage of being able to easily retrofit control units in the area of the luggage compartment.

Fiber optic cable connector, rear left in the luggage compartment



The fiber optic cable connector is located in the luggage compartment of the F01/F02, to the left behind the side wall trim. The fiber optic cable connector is arranged in the MOST bus system between the front area of the vehicle (head unit, DVD changer) and the rear area of the vehicle (TCU, VM etc.).

One or two fiber optic connectors are installed corresponding to the equipment configuration. One fiber optic connector is responsible for the factory-installed control units. The other fiber optic connector is used for the preparations for options.

The ends of the fiber optic cables, for additional options, are always grouped together on the same row in the fiber optic connector to avoid damage to the ends of the fiber optic cables.

As soon as the retrofit is installed, the fiber optic connectors are reconnected according to instructions and integrated in the MOST bus. Within the framework of programming, the control unit sequence is reloaded into the master control unit.

MOST Control Units and Light Direction

In F0x vehicles the MOST bus is used for the components in information/communication systems. The Car Information Computer (CIC) is used as the master control unit. Other bus users may be:

- DVD changer
- Instrument cluster
- Top-HiFi amplifier
- Satellite tuner SDARS (on early CIC cars)
- TCU/Combox
- Rear Seat Entertainment
- ULF-SBX high



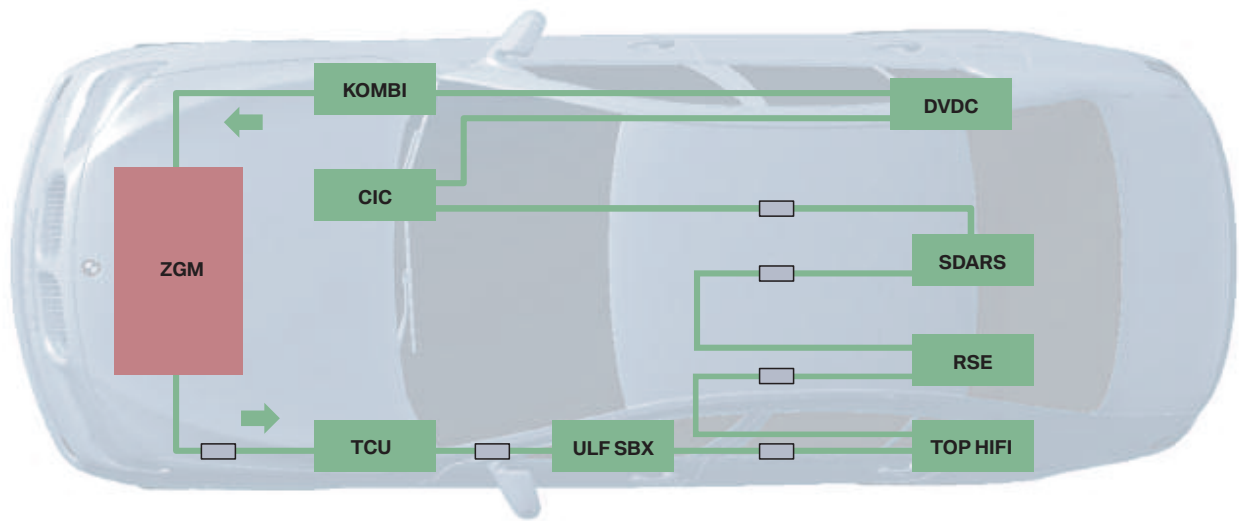
The MOST programming access used in BN2000 models is no longer required for BN2020 F0x vehicles. The programming on these vehicles is done via the Ethernet access point.

■ **Light Direction**

Data are always sent in one direction on the MOST bus. Each control unit can send data on the MOST bus.

The physical light direction runs from the master control unit (Car Information Computer) to the DVD changer, to the instrument cluster, to the central gateway module and from there to the fiber optic cable distributor. All the control units fitted in the rear end are connected at the fiber optic cable distributor. From the last control unit, the light returns to the master control unit.

MOST ring in the F01/F02



Index	Explanation	Index	Explanation
TOP HIFI	Top-HiFi Amplifier	KOMBI	Instrument Cluster
DVDC	DVD Changer	SDARS	Satellite Tuner
RSE	Rear Seat Entertainment	ULF-SBX	Interface Box
TCU	Telematics Control Unit	ZGM	Central Gateway Module
CIC	Car Information Computer		

Registration of control units in the MOST

Precisely in the same way as on the E6x models, the control units installed on the MOST bus are stored in a registration file in the master control unit. The corresponding data are stored during the production process and, in connection with control unit retrofits, after programming the respective control unit.

The control units and their order on the MOST bus are stored in this registration file. With the fiber optic cable connector, it is possible to connect control units in the rear area of the vehicle ex factory or after a repair in different order. With the aid of the registration file, the BMW diagnosis system can determine the installed control units and their order.

In addition, this registration file is also stored in the central gateway module so that there is still access to the control unit registration in the event of a fault in the MOST framework. This means that the diagnosis can be used to call up the last functional status from the central gateway module.

Although the master control unit of the MOST, the CIC, is connected to the K-CAN, it does not carry out the function of a gateway control unit. If communication on the MOST is no longer possible, the necessary data can only be read out via the central gateway module.

Bandwidths

The bandwidth indicates the capacity of the network, i.e. how many data items can be transmitted simultaneously.

The bandwidth differs considerably in the various applications.

The aim is that all vehicle occupants will be able to call up different services simultaneously, e.g.

- The driver calls up navigation information
- The front passenger listens to the radio
- A rear passenger listens to a CD
- The other rear passenger watches a DVD

Application	Bandwidth	Data format
AM-FM	1.4 Mbit/s	Synchronous
MC	1.4 Mbit/s	Synchronous
CD	1.4 Mbit/s	Synchronous
MD	1.4 Mbit/s	Synchronous
Telephone	1.4 Mbit/s	Synchronous
SBS	1.4 Mbit/s	Synchronous
VCD	1.4 Mbit/s	Synchronous
DVD	2.8 - 11 Mbit/s	Synchronous/asynchronous
Navigation	250 kbits/s	Asynchronous
Telematics service	Various	Synchronous

The data transmission rate of 1.4 Mbits/s for audio data is derived from a scanning frequency of 44.1 kHz per channel (two channels for stereo) and a resolution of 16 bit.

The bandwidth of the MOST of 22.5 Mbits/s is used in time multiplex by synchronous channels, asynchronous channels and control channels. The division in synchronous and asynchronous channels takes place to suit requirements.

Channels for control information have a smaller bandwidth of 700 kbits/s. This corresponds to approximately 2700 telegrams per second. At present there is no device that can accept and process even a third of this number of telegrams per second.

In future, the MOST will be equipped with a data transmission rate of 50-150 Mbits/s.

MOST Bus Diagnosis

Due to the differences in the configuration of the MOST bus, diagnosis methods will differ between models. However, there are many similarities and there are some basic rules which apply to all MOST equipped vehicles.

It is important to remember that on the MOST network, messages can only be transmitted provided the bus ring is complete and fully functional. If there is a ring fault in the MOST network, the diagnostic system only communicates with the instrument cluster and the Control Display because both of these modules are directly connected to the K-CAN System Bus.

The fiber optic signals on the MOST network always travel in one direction and only in one direction. Signals always originate at the Control Display or the CIC (depending on the model) and travel in and out of all the modules in the ring and back to the Control Display or CIC.

The MOST bus allows intersystem fault memory entries in the individual control modules. A feature of the system faults is that faults may be entered in a control module although the control module is OK. Conclusions may be drawn about the cause of the fault, using the fault information stored in all the control modules.

The possible system faults are:

- Optical wave guide communication fault
- A Control Module does not switch a light off (All MOST Control Modules)
- Network wake-up unsuccessful
- Ring fault diagnosis run

■ Optical Wave Guide Communication Fault

This fault indicates a problem with optical transmission. Insufficient light is being received by one of the modules in the ring. The loss of light may be caused by:

- Defective optical wave guide, Harness twisted too tightly (Min. bend radius 50mm.)
- Light output or reception sensitivity of a diode is too low
- Connector not installed correctly
- Voltage fluctuation while powering up a control module

If the fault is stored, the system triggers a reset and starts up again. The music is switched off briefly and the display screen of the Control Display continues to operate.

To find the module responsible for the fault, the fault memory of the modules must be read in MOST ring order.

Fault lies between the module with the fault code (B) and the preceding module (A).

If the voltage has dipped below 9v, the fault may be incorrectly stored. If the voltage is low perform the following test after connecting a battery charger.

1. Clear the fault memory in control module B.
2. Lower the light output in control module A.
3. Read out the fault memory in the MOST ring in order.
4. If control module B is again the first to store the fault, it can be assumed the fault lies between control modules A and B.

Then, check control modules A and B for loose connections and check the optical wave guide for kinks. If the visual inspection is OK, the fault can be located using the OPPS tester on older vehicles or optionally performing the following tests.

- Remove the input optical wave guide from control module B and confirm the presence of light. If light is present, install by-pass optical wave guide in place of control module A, clear fault codes in module B and perform ring break test. If MOST network operates properly, then control module A is at fault and must be replaced. If MOST network still has a fault, put module A back in the network and by-pass module B. Clear faults and again perform ring break test. If MOST network operates now problem is with control module B and it must be replaced.
- If light is not present at input of module B, perform by-pass of module A as above.

The possible fault scenarios are:

- Transmit diode in module A defective
- Receive diode in module B defective
- Optical wave guide fault between modules A and B
- Software error or fault in module A or B

■ **Control Module Does Not Switch Off Light**

When the MOST network is requested to sleep, the Control Display switches off the light in the MOST ring. The lack of light input is a signal to the individual control modules to switch off their light output and enter sleep mode.

If a control module does not switch off its light, all down stream control modules register the fault "A Control Module is not switching light off."



Failure of a control module to turn its light off, will cause the MOST network NOT to enter sleep mode. If the MOST network fails to sleep, the rest of the car will not be able to enter sleep mode. This will lead to battery discharge.

To diagnose, read out fault memory in MOST ring order.

The fault lies in the control module that precedes the module where the fault is first stored.

Always confirm the problem by first clearing the fault and performing the diagnosis a second time. If the same results occur, replace the defective control module.

■ Network Wakeup Unsuccessful

This fault indicates a problem with the optical transmission. An insufficient volume of light is coming through one position of the ring and may be caused by:

- Control Module is receiving no voltage
- Optical Wave Guide harness defective
- Optical Element in a control module defective (transmit or receive)
- Connector not installed correctly

A distinction must be made as to whether the fault is currently present or sporadic.

For faults currently present, run the Ring Break Diagnosis Test Plan.

For sporadic faults perform the Luminous Power Reduction Test Plan.

■ Ring Break Diagnosis

Reading out the fault memory of the Control Display (Gateway) after performing the Ring Fault Diagnostic, results in a fault of Ring Fault Diagnosis Carried Out being stored.

This fault memory is not a true fault memory entry, but only an output of additional information for relative node position.

■ Light Output Reduction

Reducing the light output of individual control modules is a convenient method of determining the area of a defect.

- Switch on the radio.
- In Control Module functions, begin to activate luminous power reduction in the individual control module (In this test the light output of the selected control module is reduced for 5 seconds and then automatically reset to normal output).
- If the optical transmission for control module A to the next control module in the ring (control module B) is OK, a slight noise may occur when the light output is reduced, however the radio will continue to play.
- If the radio goes off and comes back on again (radio volume may be reduced) in 5 to 10 seconds, the optical transmission between control modules A and B is defective. If the visual inspection is OK, the fault can be located using the OPPS tester or optionally performing the following tests.
- Remove the input optical wave guide from control module B and confirm the presence of light.
- If light is present, install by-pass optical wave guide in place of control module A, clear fault codes in module B. If MOST network operates properly, then control module A is at fault and must be replaced.
- If MOST network still has a fault, put module A back in the network and by-pass module B. Clear faults.
- If MOST network operates now problem is with control module B and it must be replaced.
- If light is not present at input of module B, perform ring break diagnostics.

■ Ring Break Test

If there is a break in the ring (a defect between two control modules) the following fault patterns may occur:

- Transmit diode of the transmitting control module defective
- Power supply of the transmitting control module defective
- Internal control module fault of the transmitting control module
- Receiver diode of the receiving control module defective
- Power supply of the receiving control module defective
- Internal control module fault of the receiving control module
- Optical wave guide between transmitting and receiving control module defective

These faults may occur alone or in combination. To diagnose a ring break, the first step is to locate the two control modules between which the transmission failure has occurred.

This is accomplished with the ring break diagnostic function. Once the two control modules have been identified and the diagnostics have been performed, remember to check the power supply and ground circuit of both modules before condemning a module.

■ Perform Ring Break Test

The ring break test mode is entered automatically when the power to all the modules in the MOST network is switched off and then switched back on. The most effective method of switching the power off and on is to disconnect the battery negative terminal for 45 seconds. This time will allow the capacitors of all the control modules to dissipate.

When the battery is reconnected the control modules wake up and in MOST network order transmit a light signal to the next module. Each module checks to see if it has received a light signal from the previous module. If the control module does NOT receive a light input signal it still transmits a signal to the next module. A relative node number of 0 is stored in the control module that did not receive a signal but that transmitted one.

The MOST master control unit receives the light signal back and identifies which modules responded.

Go to “Control Unit Functions” Control Display Gateway and read fault memory.

The MOST master control unit will display a relative node number. This number will indicate how many modules communicated after the module which set the relative node number of 0.

To find the control module with the relative node number of 0, count from the input side of the MOST master(counting the MOST master as 0) towards the control modules.

When arriving at the control module with the number as displayed as the relative node number, the last known communicating module has been found.

Example:

While performing the ring break diagnostics on an E65 the Control Display has set a relative node number of 2. Count the Control Display a 0, the Kombi will be 1 and the ASK will be 2.

The ring break occurs between the ASK and the module which precedes it, the telephone module.



When counting control modules, the multimedia changer (if equipped) and the Nav system must be counted as two control modules.

Note: More details on the ring fault diagnosis can be found in the functional description MOST bus: ring fault diagnosis complete vehicle -> Body -> Bus functions -> MOST functions -> Ring fault diagnosis.

■ Status Wakeup

MOST control modules require high current during standby operation and must be disconnected or put in sleep mode to prevent the vehicle battery from being discharged. In case of a fault on the MOST network that continuously wakes up, the entire MOST bus will be woken up. The Control Display will wake up the CAN Bus and all the vehicle busses will be woken up. This will lead to battery discharge.

It is of great benefit to know which module initiated the wake up call. In order to find out which MOST node woke up the MOST bus, the following procedure is performed - In Control Unit Functions, press "STATUSWAKEUP"

Three different response are possible:

- Control Module woke up
- Control Module woken up
- Control Module not initialized

The Control Module with the status "Control Module woke up" is the module that woke up the rest of the MOST bus.

This diagnosis only informs which control module woke, not the reason for the wake up, diagnostic testing should be performed on the control module and related equipment.



For more information refer to the following FUBs:

- **FUB-FPA-CHA1003FP-656582005 Fault profiles, MOST**
- **FUB-DAA0302FB-656582004 MOST bus: Ring fault diagnosis**
- **FUB-BLB0704FB-657761055 MOST bus: Ring fault diagnosis**
- **FUB-DAA0701FB-656582003 MOST bus**
- **FUB-DAA0302FB-656582005 MOST bus: status wake-up**

Sub-bus Systems

Sub-busses are also used in addition to the main bus systems. Sub-bus systems are subordinate serial bus systems.

The most important sub-bus systems are outlined below:

- K-Bus
- LIN-Bus (Local Interconnect Network Bus)
- BSD (Bit-Serial Data Interface)

Data rates

Main bus system	Data rate	Bus structure
K-Bus	9.6 kbits/s	Linear - one-wire
BSD	9.6 kbits/s	Linear - one-wire
LIN-Bus	9.6-19.2 kbits/s	Linear - one-wire
LoCAN	500 kBits/s	Linear, two wire

K-Bus

The K-Bus is a bidirectional one-wire interface. This means the K-Bus has only one single line for data transmission. Bi-directional means that the data are transmitted in both directions.

The term "K-Bus (protocol)" is used for a series of sub-bus systems in the bus overview. These sub-bus systems are used for various purposes. The K-Bus protocol used here is a common component already used in predecessor models. The protocol is used in F0x vehicles, e.g. on the following systems:

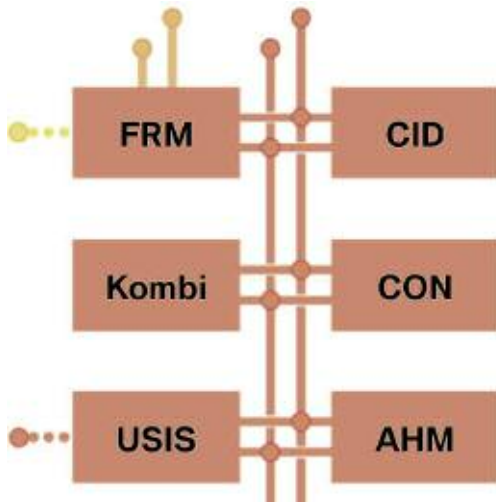
- Connection between ACSM and TCU
- Comfort Access
- CAS-Bus

Consequently, it is possible to only transmit or receive at any one time. The data transmission rate of the K-Bus is 9.6 kbits/s.

The voltage level is between 0 V and 12 V when a message is sent on the K-Bus.

The voltage level changing from 0 V to 12 V corresponds to logic 1. Logic 0 is when the voltage changes from 12 V to 0 V.

K-Bus in the E90



Voltage level on the K-Bus

The K-Bus is used as a main bus or sub-bus system depending on the vehicle model.

LIN-Bus

The LIN-Bus was developed to provide a standard network for the automobile industry.

The LIN-Bus has been used as early as the E60 and was also used to control the outside mirrors on the E46. Mainly, the versions V2.0 or higher are used in F0x vehicles.

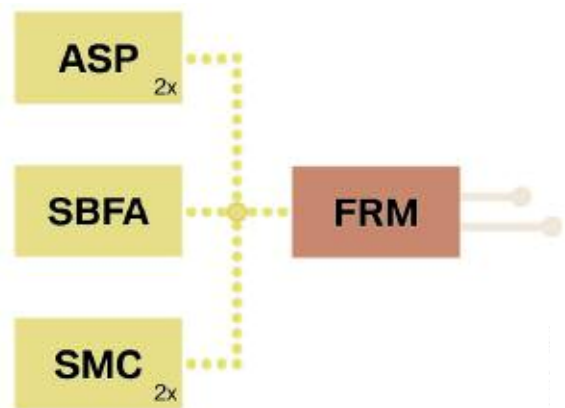
Standardization saves costs in:

- Development
- Production
- Vehicle servicing

The LIN-Bus system comprises the following components:

- Higher-ranking control unit (master)
- Lower-ranking control units (secondary control units)
- One-wire line

LIN-Bus in the E90



A bidirectional one-wire bus line serves as the transmission medium for the LIN-Bus. The bus protocol is divided strictly hierarchically in master and secondary control units. A maximum of one master is permitted for a LIN-Bus system.

The data transmission rate of the LIN-Bus can be up to 19.2 kbits/s.

The following transmission speeds are possible:

- 2.4 kbits/s
- 9.6 kbits/s
- 19.2 kbits/s

The LIN-Bus is currently installed in the following systems:

- Air conditioning (9.6 kbits/s)
- Between the driver's door module and driver's door switch cluster (19.2 kbits/s)
- Tire pressure control (9.6 kbits/s)

The LIN-Bus master forwards the requests of the control unit to the secondary control units (lower-ranking or subordinate control units) in its system.

The LIN-Bus master controls and monitors the message traffic on the bus line.

The current messages are transmitted cyclically by the LIN-Bus master.

LIN-Bus secondary control units of the air conditioning system are:

- Actuator motors for the air distribution flaps
- Blower regulator
- Electric auxiliary heater

The LIN-Bus secondary control units wait for commands from the LIN-Bus master and communicate with it only on request.

A LIN-Bus secondary control units can send the wake-up sequence of its own accord in order to end sleep mode.

The LIN-Bus secondary control units are installed in the users of the LIN-Bus system (e.g. stepper motors for fan flap adjustment).

Due to the lower data rate on the LIN-Bus, terminal resistors are not used.

In F0x vehicles, the following control units still correspond to the V1.x specification:

- Belt hand-over
- Outside mirror
- Blower output stages
- Intelligent Battery Sensor

LIN V2.0 (or V2.1)

LIN components that correspond to the specification of data protocol LIN V2.0 or higher have extended functions.

- The LIN components for V2.x are delivered with a device ID and a base configuration. The final (dynamic) configuration and the allocation of the ID number take place on commissioning by the master control unit.

If one of these components is replaced, this operation must be initiated manually by means of the BMW diagnosis system.

- The data protocol has become more variable, permitting, if required, periodic alongside sporadic messages as of specification V2.0. These "sporadic frames" are only sent if the master control unit requires data from the secondary control units or outputs data. Without such a request, the time slots in the messages remain empty.
- The master control units can send so-called multiple requests to secondary control unit groups. To reduce the bus load, the contacted secondary control units only respond in the case of changed values (e.g. door contact). All master control units of the LIN V2.x specification are downwardly compatible to (secondary control units) components of previous specifications.

However, all V2.0 secondary control units also require a V2.x master controller.

A number of the connected components are only diagnosis-capable to a limited degree, for example the rain-light-solar-condensation sensor.

In this case, the master control unit serves as the gateway to the remaining bus system. The diagnosis requests from the ZGM or BMW diagnosis system are inserted in the sporadic section of a LIN frame.

A special feature introduced with BN2020 in the F01/F02 is that the data communication between the Comfort Access and diversity antenna is implemented with 20.0 kBit/s due to the large number of small data packages.

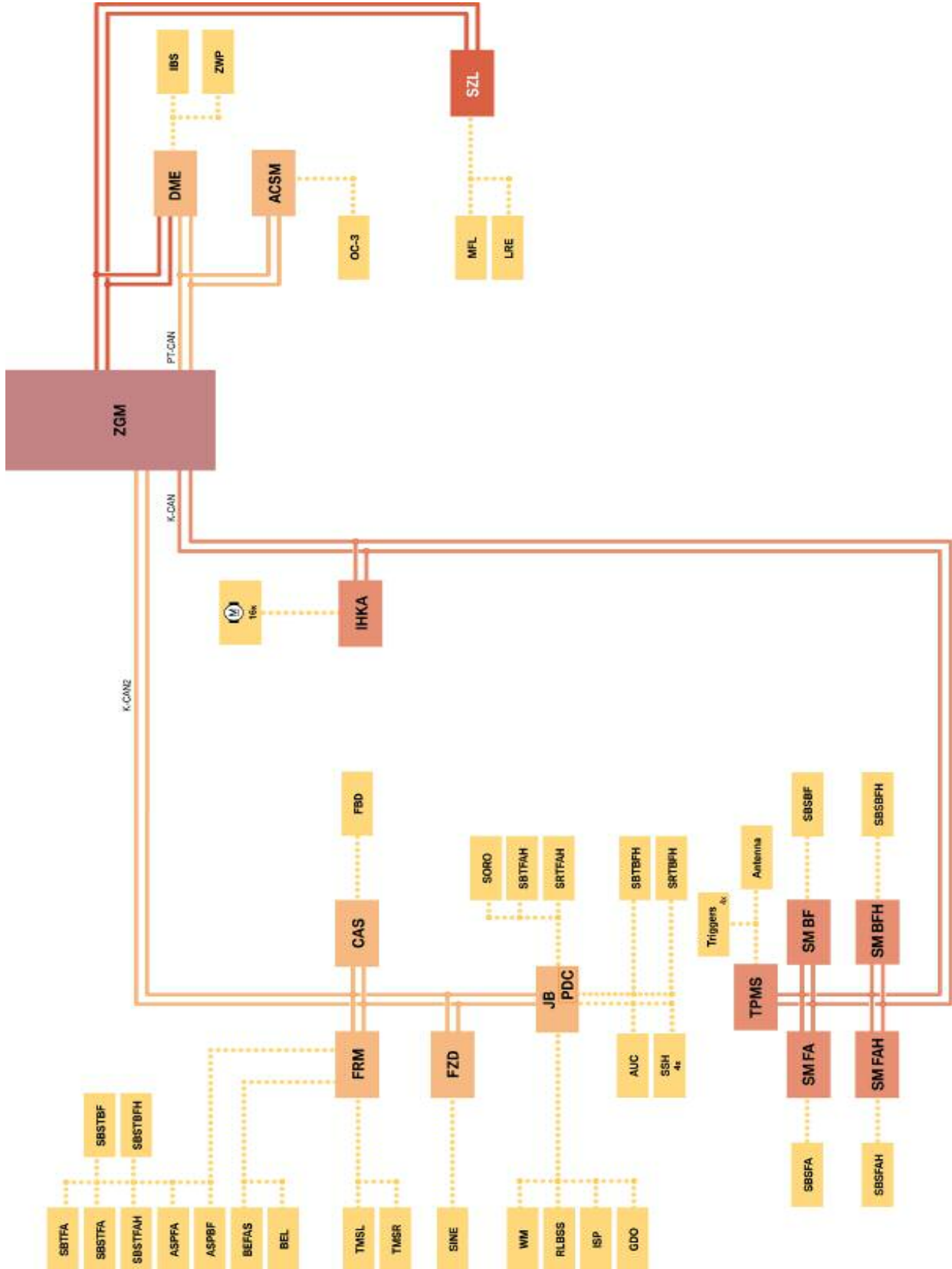
The slightly higher transfer rate means that the time slots in the data protocol can be better exploited. The master control unit sends the "sleep command" to place the LIN in the idle state.

The "sleep command" can also be sent with terminal R "On", e.g. for mirror adjustment. The "wake-up command" can also be sent by a secondary control unit.

The LIN messages in the data protocol are divided into four sections:

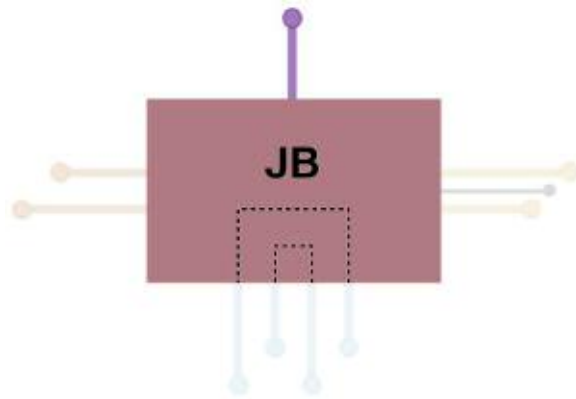
- Synchronization
- Identifier
- Data
- Checksum

F0x vehicle LIN Bus overview



D-Bus

The diagnosis bus or D-Bus represents a physically separate access facility to the outside. Interacting with the gateway (junction box), it enables access to all data busses. When a diagnosis unit is connected, on request of the gateway, specific system information relating to the vehicle are made available via the diagnosis bus. A complete list of control units installed in the vehicle is transferred together with the self-diagnosis information. The data transmission rate of the D-Bus is 10.5 - 115 kbits/s.



D-Bus in an early E90

D-CAN

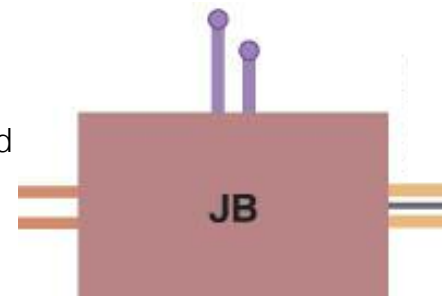
In order for BMW to meet the requirements of standard ISO 15765 (Diagnostics on CAN with KWP 2000 [Keyword Protocol 2000] or UDS [Unified Diagnostic Service]) D-CAN (Diagnostics on Controller Area Network) replaced the D-Bus diagnostics interface worldwide.

This legal requirement in the USA mandates that all vehicles be equipped with the D-CAN as from model year 2008. BMW began the transitional phase in September 2006. The E70 was one of the first new vehicles equipped with D-CAN and then the modification was phased-in on all other BMW models.

The D-CAN data-signalling rate is 500 kbit/s.
The measured resistance between the wires should be 60 Ω .

An OBD-tool or BMW diagnostics system is automatically detected and distinguished during data output. The second TXD interface (pin 8) is not necessary.

The ICOM A provides the interfaces for connection to the vehicle OBD II female diagnostic interface connector. A powerful computer core enables it to work as a protocol converter to assume the data interchange between the tester and the vehicle control units as well as the signal processing for connection of the measurement system (IMIB).



D-CAN as from E70

Power is supplied by way of KL 30 across the vehicle interface. ICOM A is rated for a minimum voltage of 8 V. Stable operation is only ensured if the power supply is above the minimum voltage limit.

ICOM A can be connected to the workshop network by a Ethernet LAN cable (wireless connection by WLAN will be available in the near future). The maximum data rate is 100 Mbit/s. Or directly to the ISID on offline mode.

The communication with the MOST Bus (for programming) is supplied by ICOM B on BN2000 vehicles. For this purpose ICOM B (2) is to be connected with the ICOM A (1) by way of a supplied USB cable (3). The host communication is thru either a workshop network LAN connection (4) or WLAN.

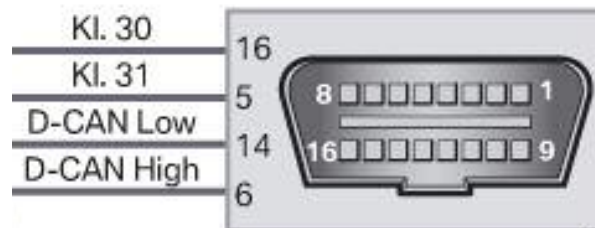
Note: With BN2020 vehicles (F0x) diagnosis and programming is done through ISID with ICOM A only (programming done through ethernet connection).

OBD II access in all vehicles remains unchanged; The diagnosis socket is located under the dashboard on the driver's side.

The pin assignments at the OBD II connector are as follows:

- 3, 11, 12, 13 = Ethernet connections. (F0x vehicles)
- 16 = Terminal 30
- 5 = Terminal 31
- 14 + 6 = Communication connections
- 8 = Activation of Ethernet

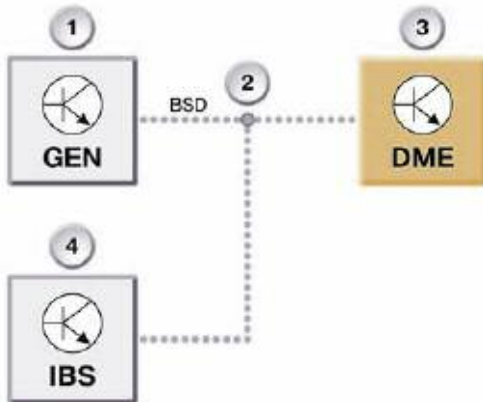
The diagnosis socket is located under the dashboard on the driver's side.



Bit-serial Data Interface

The bit-serial data interface is used to connect the alternator and the intelligent battery sensor to the digital motor electronics.

Overview of bit-serial data interface



Index	Explanation
1	Alternator
2	Bit-serial data interface
3	Digital motor electronics
4	Intelligent battery sensor

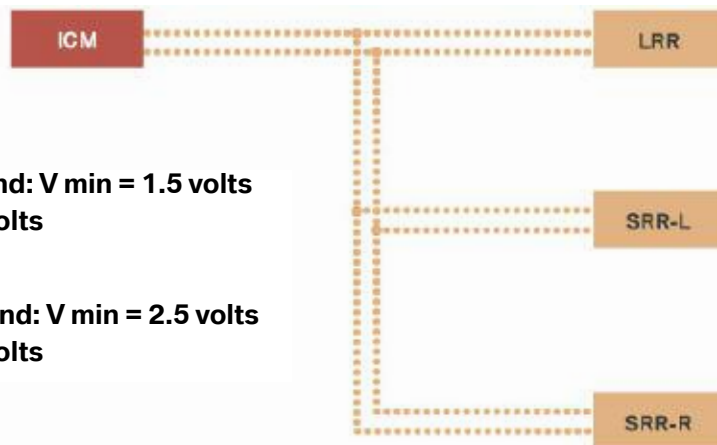
Scope voltage when binary 0 is ~12v

Scope voltage when binary 1 is ~900mv

Local-CAN

The Local-CAN serves to transfer the high data volumes of the Short-range and long range radar sensors to the ICM in F0x vehicles with.

The Local-CAN has a data transfer rate of 500 kBit/s and is designed as a twisted pair of wires. The 2 (120 Ω) terminal resistors in the Local-CAN are located in the ICM and the long range radar sensor which equal to a measured resistance between the wires of 60 Ω .



CAN Low to ground: V min = 1.5 volts and V max = 2.5 volts

CAN High to ground: V min = 2.5 volts and V max = 3.5 volts

The Local-CAN is also used in Night Vision 2 (F0x) system for diagnosis, programming and camera control.

The camera is programmed through the NVE control unit. The control unit receives the programming data for the camera through PT-CAN. The control unit forwards this data to the camera through the Local-CAN.



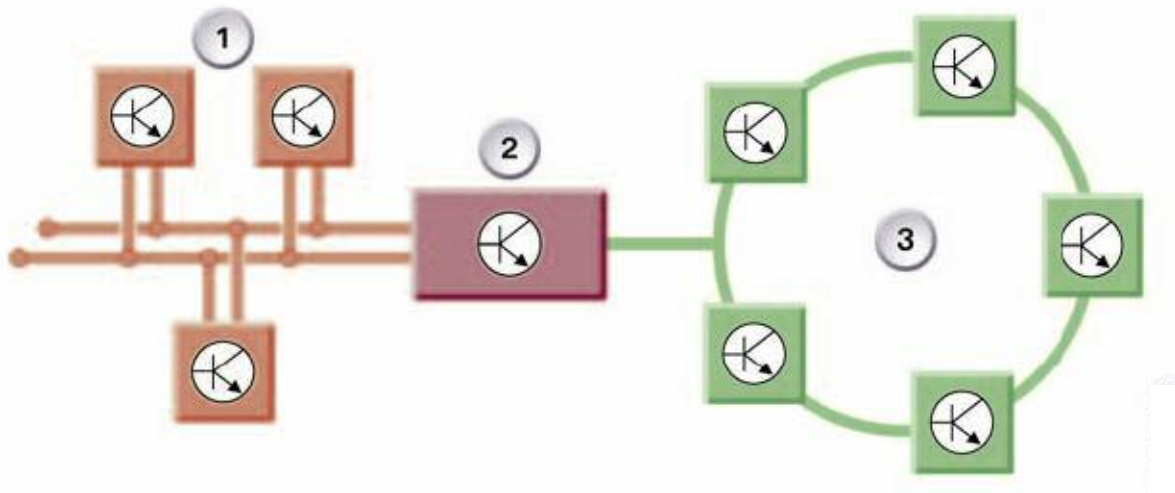
When measuring Local-CAN voltage, the Oscilloscope (IMIB) settings should be the same as for the PT-CAN and K-CAN 2 (refer to these for an sample of the Local-CAN scope pattern).

Gateways

Data exchange between the bus systems Gateways serve the purpose of coupling different types of bus systems, i.e. gateways connect bus systems with different logic and physical properties.

They therefore ensure data exchange despite the different transmission rates of the individual bus systems.

Example of a gateway connection



Index	Explanation	Index	Explanation
1	Linear bus system (e.g. KCAN)	3	Ring-structure bus system (e.g. MOST)
2	Gateway (e.g. M-ASK)		

A gateway performs a dual function:

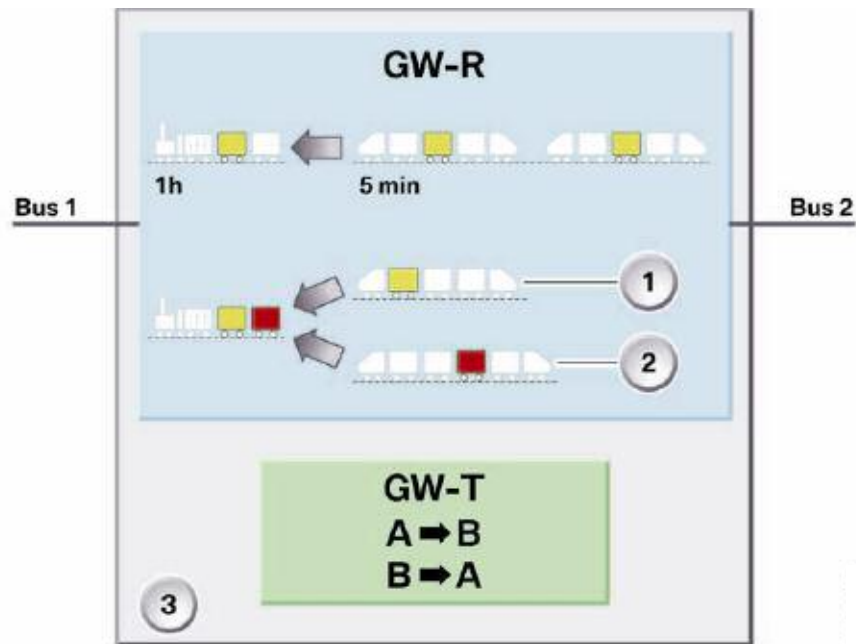
- To collect information from various different networks.
- To send information to the correct network.

Transmission rates, data volume and priority stages of the individual messages are filtered in the gateway and buffered if necessary.

The gateway converts the messages to suit the respective bus system based on gateway rules and conversion tables.

The respective bus system is now served and the messages reach their target address. If necessary, messages that are not so important remain in the gateway memory. These remaining messages are then sent later.

Gateway Rules Based on the Example of a Train Station



Index	Explanation	Index	Explanation
GW-R	Gateway rules	Bus 2	Slow bus
GW-T	Gateway table	A → B	Table example: Message from A to B
1	Train 1 with yellow message	B → A	Table example: Message from B to A
2	Train 2 with red message	5 min	5-minute intervals
3	Gateway	1h	1-hour interval
Bus 1	Fast bus		

The express train 1 arrives at the station in 5-minute intervals. This train has a message (yellow) for the train with the steam locomotive. The message is transferred to the first wagon of the train with the steam locomotive.

In the meantime, an express train 2 arrives with a message (red) for the train with the steam locomotive. Since the steam locomotive has not yet departed, the second message is also transferred to the steam locomotive and attached after the first wagon. This procedure is repeated until the train with the steam locomotive leaves the station after one hour.

The messages are parked in the station when the train with the steam locomotive is fully loaded. When available, a new train with a steam locomotive is loaded with these messages.

NOTES

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